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A HUMAN ENGINEERING EVALUATION OF VISIBILITY FROM THE DDH280 BRIDGE

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A HUMAN ENGINEERING EVALUATION OF VISIBILITY FROM THE DDH280 BRIDGE

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ABSTRACT

General visibility requirements were reviewed in the horizontal and vertical fields of view for destroyer bridges. These requirements were related to direct observations and measurements made on board the DDH280 class destroyers. Specific deficiencies were established and recommendations for improvement were developed. Computer simulation of existing and proposed bridge layouts were utilized to establish optimum positions for primary workstations and to support analysis of the DDH280 bridge. Particular attention was paid to the placement of pelori within the bridge to ensure that good overall visibility was available for taking visual bearings.

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CHAPTER 1

INTRODUCTION

1.1. Background to the Tasking

In December 1982 the Directorate of Marine and Electrical Engineering (DMEE) requested the Defence and Civil Institute of Environmental Medicine (DCIEM) to undertake a human engineering analysis of the DDH280 class bridge. The project was one of a number carried out in support of the Tribal Class Update and Maintenance Program (TRUMP) to improve the capability of the Canadian destroyers. This report is an account of the study of visibility requirements subsequently carried out at DCIEM and the conclusions reached concerning bridge design.

The importance of visibility in bridge operations warrants its study as a separate topic. In close pilotage, visual fixing provides the most accurate means of establishing the ship's position. Continuous monitoring of another ship's visual bearing provides one of the most reliable indications of the risk of collision. Further capabilities for aspect recognition and identification establish visual tracking of shipping, when possible, as the best method for assessment of the risk of collision. When refueling at sea within 30 meters of the supply ship, only visual inspection presently provides sufficient noise free resolution for fine manoeuvring. Despite the evolution of the operations room, with its high technology displays, the unique visibility afforded by the bridge has continued to weigh heavily in support of its role as the centre of command and charge of the ship.

1.2. Objectives of the Study

The study was directed towards the following objectives:

- Reducing the probability of human error which might affect the safety of the ship, or any accompanying ships;
- Reducing or eliminating instances of excessive workload demands on the bridge complement;
- Contributing to the operational capability of the ship;
- Maximizing the utilization of the bridge complement.

1.3. Conduct of the Study

The first stage of the work at DCIEM consisted of a review of requirements for visibility in the horizontal and vertical planes. In this context, a number of bridge design standards produced for allied naval and merchant marine vessels were reviewed.

The second stage of work consisted of visits to HMCS ATHABASKAN and HMCS HURON to gain experience in current operations and to examine the existing bridge. Following the familiarization period, deficiencies in the design of the DDH280 bridge were identified (1). Alternative bridge designs were examined and full scale mock-ups were constructed for four proposals and the existing layout (2).

A review of the requirements for visibility and the factors affecting it was then conducted. The factors identified as affecting visibility were:

- size of bridge;
- shape of bridge;
- window size and height;
- mullion size;
- personnel positions;
- personnel movements;
- number of bridge personnel.

Potential modifications were then examined against each of these factors to establish their impact on the visibility within the bridge.

Computer models of the visibility provided by the existing bridge were developed. Arcs of visibility through each window were calculated and totalled for selected positions on the bridge. Positions were chosen sufficiently close to one another to permit maps of the total arcs of visibility to be constructed. Calculations were verified by comparison with arcs measured from the pelori positions of HMCS ATHABASKAN and HMCS HURON. Bridge design proposals were evaluated by constructing similar maps for alternative window sizes and alignments.

CHAPTER 2

VISIBILITY IN THE HORIZONTAL PLANE

2.1. General

Requirements:

a. Analysis of destroyer operations has indicated the importance of good visibility from the primary bridge workstations (3). The obligation to provide good visibility out to the horizon has been established for lookouts and the Officer of the Watch (OOW) (4). Therefore, every attempt should be made to provide as much of the 360 degree arc of horizontal visibility as possible.

b. The requirement for horizontal visibility from the bridge can be determined at three levels:

- ideal FOV (Field of View);
- likely maximum FOV;
- minimum acceptable FOV.

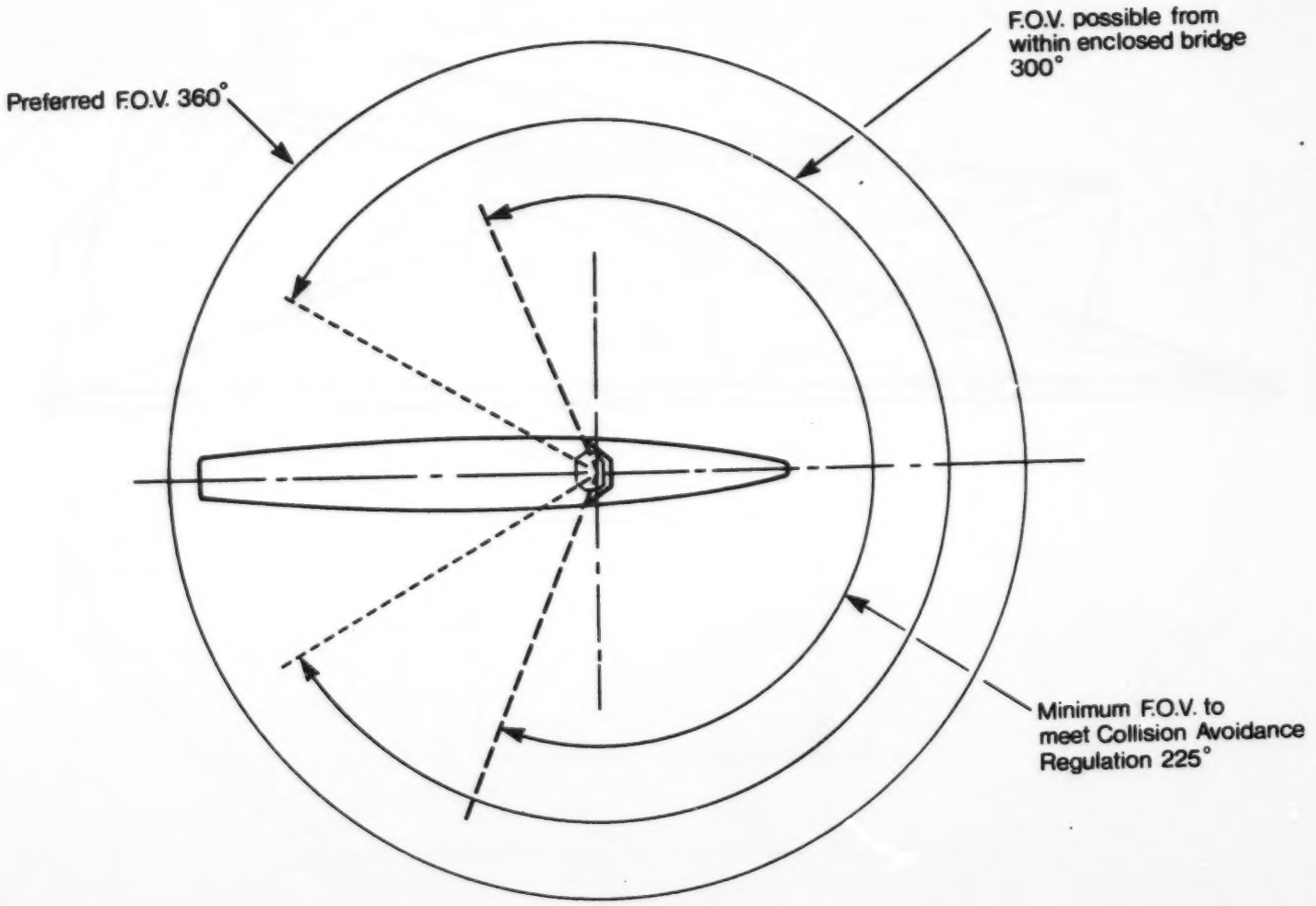
c. The ideal FOV, given the operations undertaken by modern warships, should obviously provide the OOW with unobstructed vision in the horizontal plane throughout 360 degrees from the principal conning position (5).

d. The likely maximum FOV, given that from the bridge, vision aft is invariably obstructed by masts, funnels, superstructure and helicopter hangar, is generally less than 360 degrees. What constitutes an acceptable reduction from 360 degrees is difficult to determine. Prior to the development of the enclosed bridge, 300 deg. of unwooded panoramic vision was the standard on RN ships (6) and 300 deg. of vision including window mullions appears to be possible from within a modern enclosed bridge (see Section 2.5).

e. The minimum acceptable FOV is that dictated by the lookout requirements implicit in the International Regulations for Preventing Collisions at Sea, 1972. These make the give-way vessel responsible for taking action to avoid other vessels crossing within "two points abaft the beam". Thus the OOW should have a clear view $\pm$ 112.5 deg. from the line of advance. This corresponds to the recommendation (7) that 225 deg. of panoramic vision should be provided from the bridge (see Fig. 1)

FIGURE 1

Requirements for horizontal field of view


Preferred F.O.V. 360°
F.O.V. possible from within enclosed bridge 300°
Minimum F.O.V. to meet Collision Avoidance Regulation 225°

f. While this minimum standard may be sufficient for ships making headway, it is insufficient for ship handling operations which require critical manoeuvres to be conducted when running astern or at close quarters with other ships. For ships with a forward bridge, the minimum standard for all round visibility is 360 deg. using not more than two positions in the bridge (8).

Observations:

Measurements taken onboard, as well as computer modelling, have confirmed that the ideal 360 deg. overall visibility is not available from a single position on the DDH280 bridge. The minimum horizontal field of view of ± 112.5 deg. is available along the centreline two metres aft of the forward window. The largest arc of visibility is 146 degrees (see Fig. 11, Section 2.5).

The requirement for 360 deg. arc of overall visibility from not more than two positions cannot be met within the enclosed DDH280 bridge. Some impression of the consequences of this can be gauged from the extent of wing to wing movement recorded for the captain of HMCS ATHABASKAN during berthing and slipping (Fig. 2).

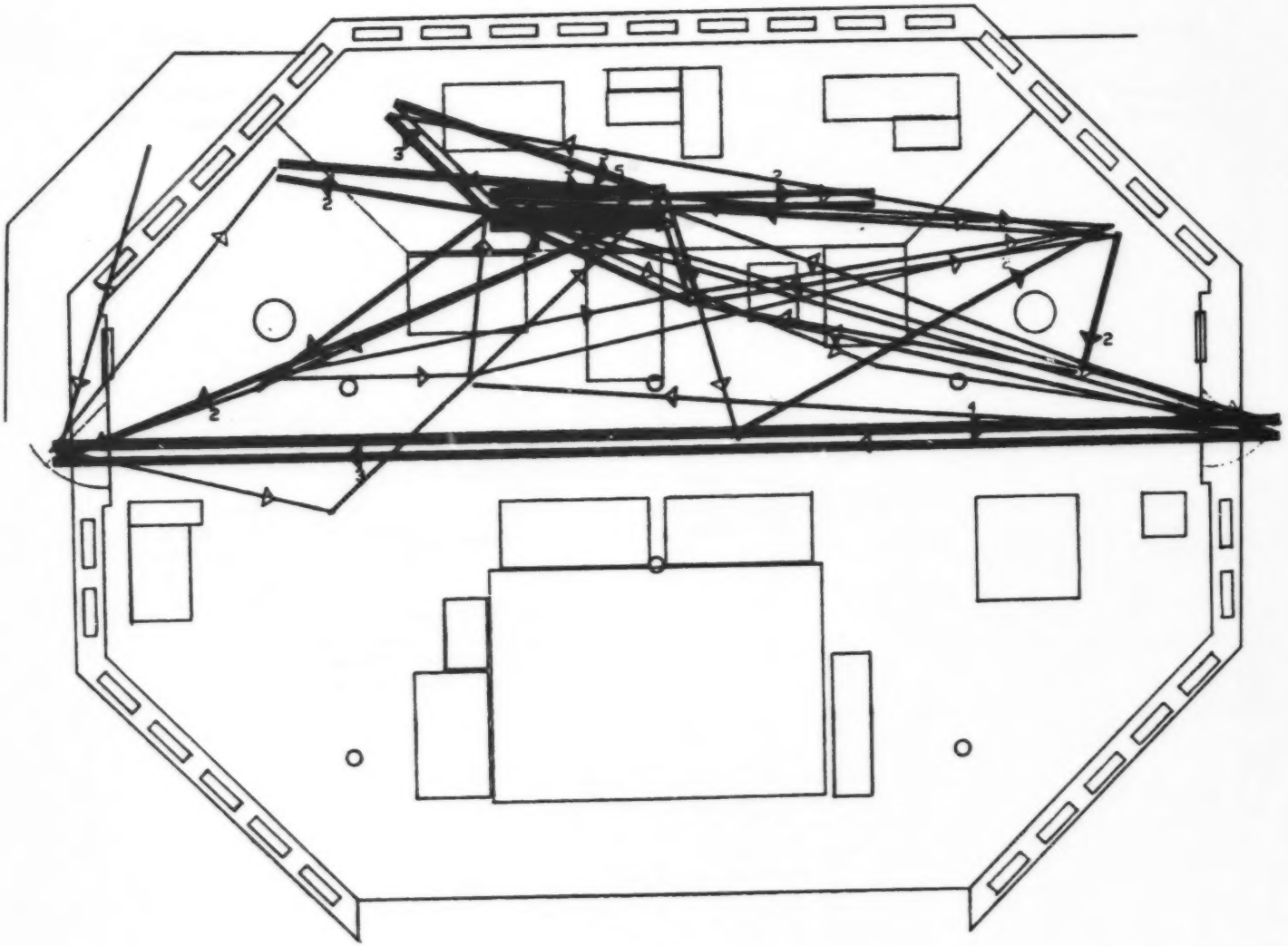
Recommendations:

The poor horizontal visibility within the DDH280 bridge is the consequence of a number of factors. It can be expected, therefore, that no single modification will rectify all of these problems. A number of changes can be recommended which collectively relieve or compensate for the observed deficiencies:

1. Re-locating workstations;
2. Re-orienting workstations;
3. Providing greater access to the windows and free movement along the windows;
4. Reducing congestion in the forward bridge;
5. Installing closed circuit television cameras to cover blindspots;
6. Installing windows in the wing doors;
7. Increasing the size of the bridge windows;
8. Reducing the mullion size;
9. Re-orienting some of the windows.

FIGURE 2

Movement patterns of the commanding officer



Total distance travelled was 1040 feet

These changes will be dealt with in greater detail later in the report.

A number of the changes recommended above have been incorporated within several bridge layout proposals (9). It is important, however, to expand on a number of issues affecting visibility on the bridge separately, so that the principles employed in the development of the layout proposals can be understood.

2.2. Vision from the Bridge Wings

Requirements:

a. Bridge wings are intended to provide excellent vision down the sides of the ship for critical operations such as docking, un-docking, RAS, etc. Therefore, they should provide visibility not only along the waterline on the side of the ship, but also across the bow and stern. The extent of overlap required has not been well documented: approximately 15 deg. of bow overlap (i.e. 195 deg. coverage) would appear to be the minimum. For the Canadian Patrol Frigate (CPF) the requirement has been stated as 25 deg. bow overlap and 15 deg. stern overlap (10).

b. The bridge wings should not interfere with the vision of the OOW from within the bridge (see Fig. 3). This requirement can conflict with requirements for wing visibility, because wide wings which provide good vision across the bow can obscure the view of the OOW from within the bridge on the beam.

c. In the past this conflict has been resolved by three approaches:

i. locating the wings aft of the centreline conning position (the outstanding example of this approach is the RN Type 12 Whitby and Rothesay class frigates);

ii. locating the wings lower than the bridge deck (as on the Belgian E-71 class);

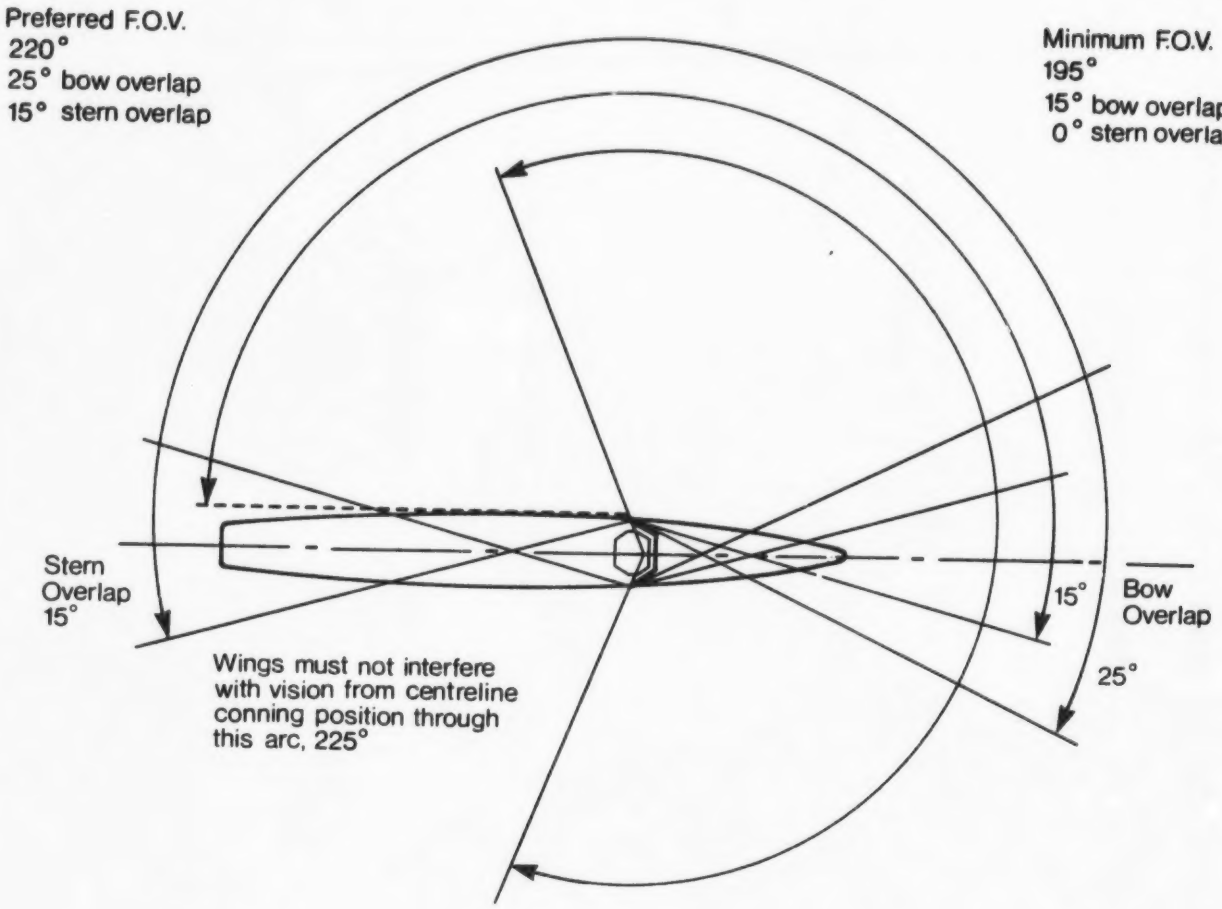
iii. making the width of the wings small in comparison to the width of the bridge (as on the DDH-280 class).

However, each of these approaches involves some compromise between the vision requirements of the bridge and those of the bridge wings.

d. The ship's side should always be visible from the bridge especially where tugs or pilots' boats come alongside and where the ship touches the jetty (11).

FIGURE 3

Requirement for vision from the wings



Observations:

The DDH280 class bridge wings provide 45 deg. bow overlap but no stern overlap. The stern of the ship cannot be seen from any point on the bridge.

The wing bulwarks interfere with the OOW's view of the sea close to the ship particularly as he approaches close to the wing windows.

It is not possible to see the side of the DDH280 toward the after quarter from the bridge wings, because the bridge is positioned well forward of the 15.25 m (50.0 ft) maximum breadth of the ship.

Recommendations:

No major improvements to bridge wing visibility can be obtained without major structural modifications. Close circuit television cameras should, therefore, be installed to provide visual coverage of blindspots on the stern and along the sides of the ship.

2.3. Effect of Bridge Size on Visibility

Requirements:

a. The overall size of a bridge has a significant impact on the visibility available. This is primarily due to the geometry involved in looking through windows. The relationship of the field of view afforded by a window, and the viewing distance to the window is illustrated in Fig. 4. The nominal window size is 650 X 495 mm (25.5 X 19.5 in), the size of the existing DDH280 windows. From the figure it is possible to appreciate the rationale for the recommendation (12) that the bridge be 3.3 metres (10 ft.) in diameter. Figure 5 relates the field of view obtainable from these windows to the overall design of the bridge, by illustrating the viewing distance from the OOW position to side and rear windows of a typical bridge layout. It can be seen that the fore-aft depth of the bridge would have to be reduced significantly if vision from the centreline conning position through the aft windows is to be improved.

b. These effects are much less apparent to the observer than the calculations suggest simply because the observer, as a matter of course, moves to locations which improve his view of the area of interest. However, this reaction leads to almost continual movement about the bridge by the OOW, aggravating the freedom of movement problem (13).

FIGURE 4

Relationship between arcs of visibility and distance from window, 495 mm wide by 650 mm high

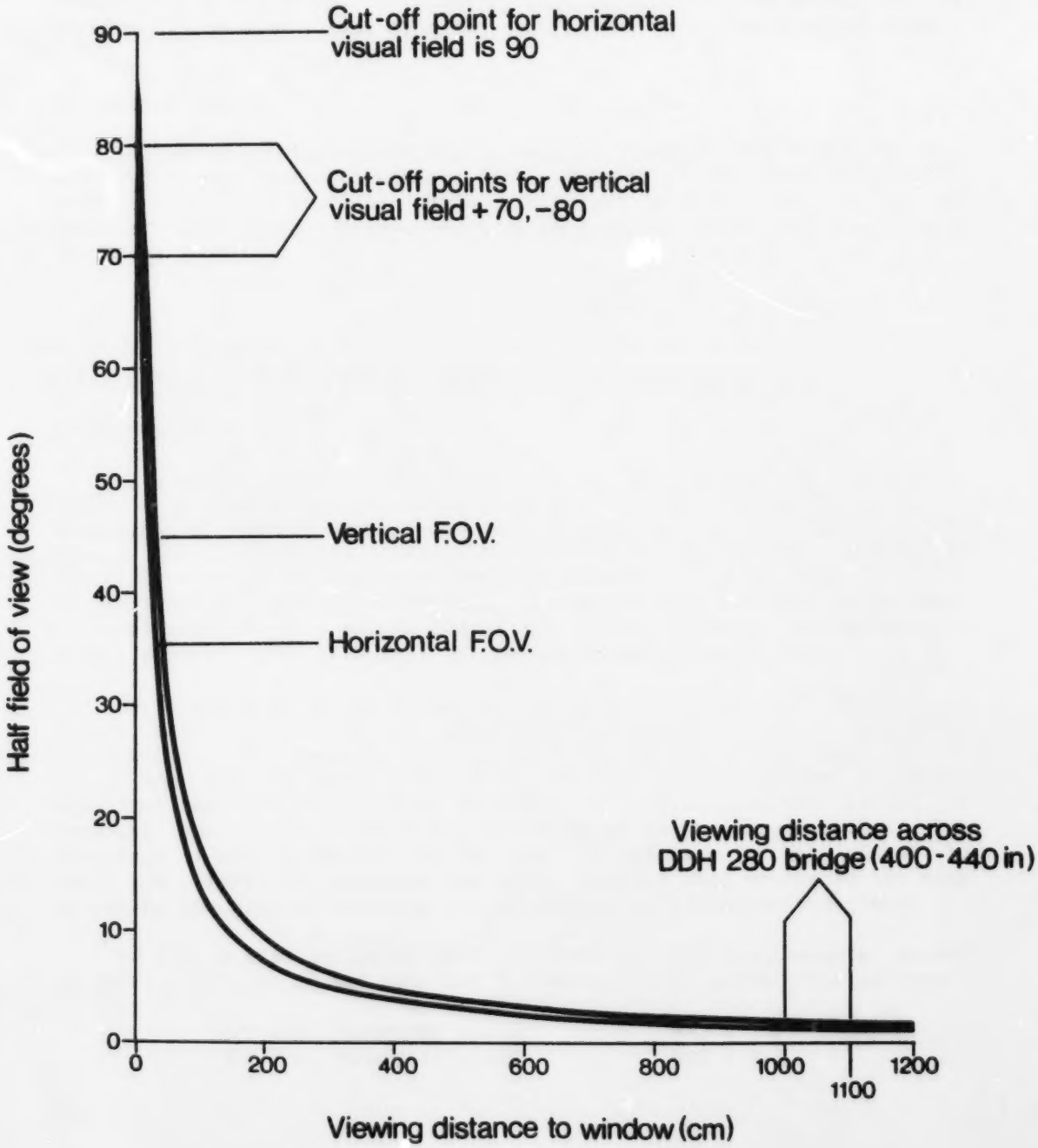
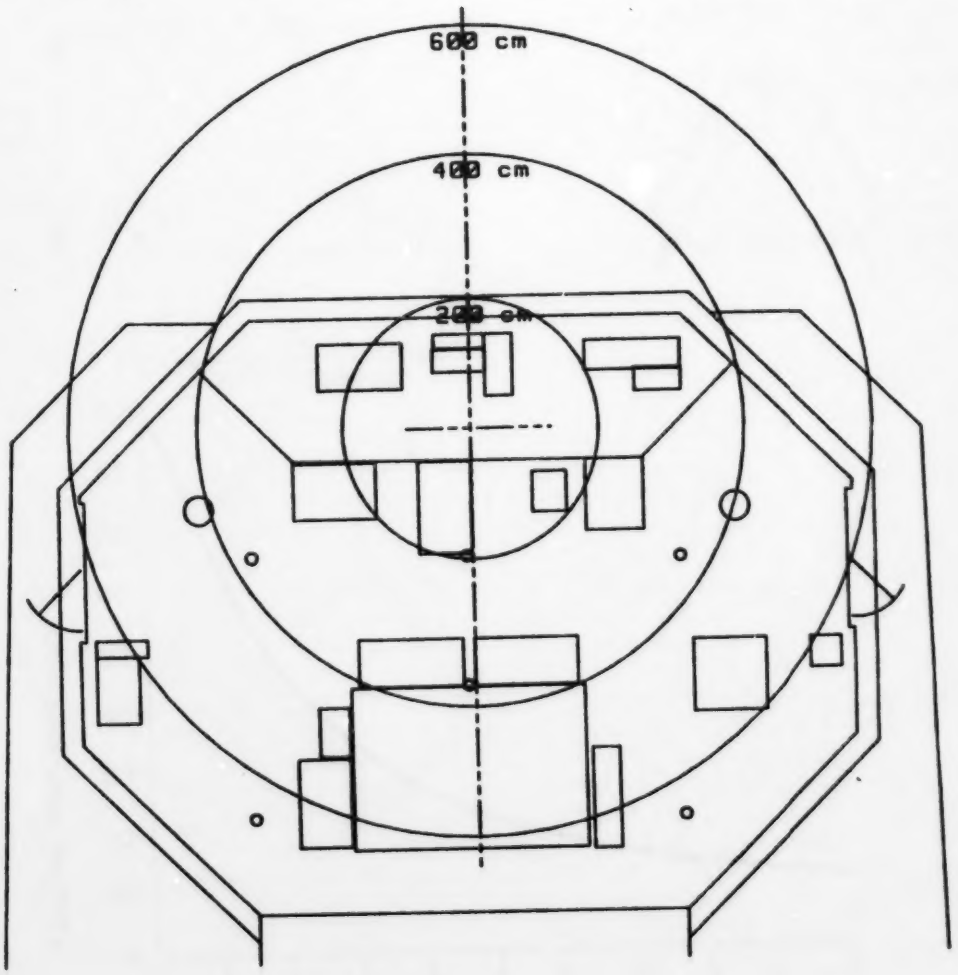


FIGURE 5

Viewing distance to the windows in the DDH 280 bridge from the centreline conning position



Observations:

The size of the DDH280 bridge (13.44 m X 8.65 m) has a significant impact on visibility. The large bridge incurs poor visibility, and forces the OOW to move about in order to be able to obtain a good view of all areas around the ship. The existing side windows provide only 5 deg. of horizontal arc when viewed from the centreline, more than 5 meters away.

Recommendations:

The maximum bridge width should be approximately five times the window width, the preferred maximum depth would be of the order of three to three and one half times the window width (see Section 2.4). Since the size of the DDH280 bridge must be regarded as fixed, the window size should be increased.

2.4. Effect of Bridge For-Aft Depth on Panoramic Vision

Requirements:

a. In modern warships the view aft of the bridge is invariably obscured by superstructure, funnels, masts, etc. The visibility abaft the beam improves considerably as one moves forward of the aft bulkhead. In Fig. 6, the relationship between the distance forward of the bulkhead and the field of view is shown. The data are dimensionless, so that they can be applied to any size of ship. Visibility also improves in the most critical area, forward of the bow as one moves forward. It should be noted, however, that this gain is limited by available windows.

b. In addition to the field of view from the bridge centreline, the figure shows the field of view available abaft the beam as one moves athwartships. For example, suppose the width of the aft bulkhead, W, is 10 m and the OOW moves 1 metre (0.1 W) from the centreline. It can be seen that the effect of such an excursion is identical to the effect of reducing the width of the aft bulkhead by twice the amount (0.2 W). The advantage of moving forward, rather than athwartships is that vision to port and starboard improves equally, whereas when moving to the side vision on one side is improved at the expense of vision on the other.

c. Fig. 6 also indicates that the field of view requirements stated in Section 2.1 can be met with the following bridge depth:width ratios:

225 deg. panoramic vision	W/D = 5.0
300 deg. panoramic vision	W/D = 1.2

FIGURE 6

Rearwards visibility as a function of distance forward from rear bulkhead of bridge

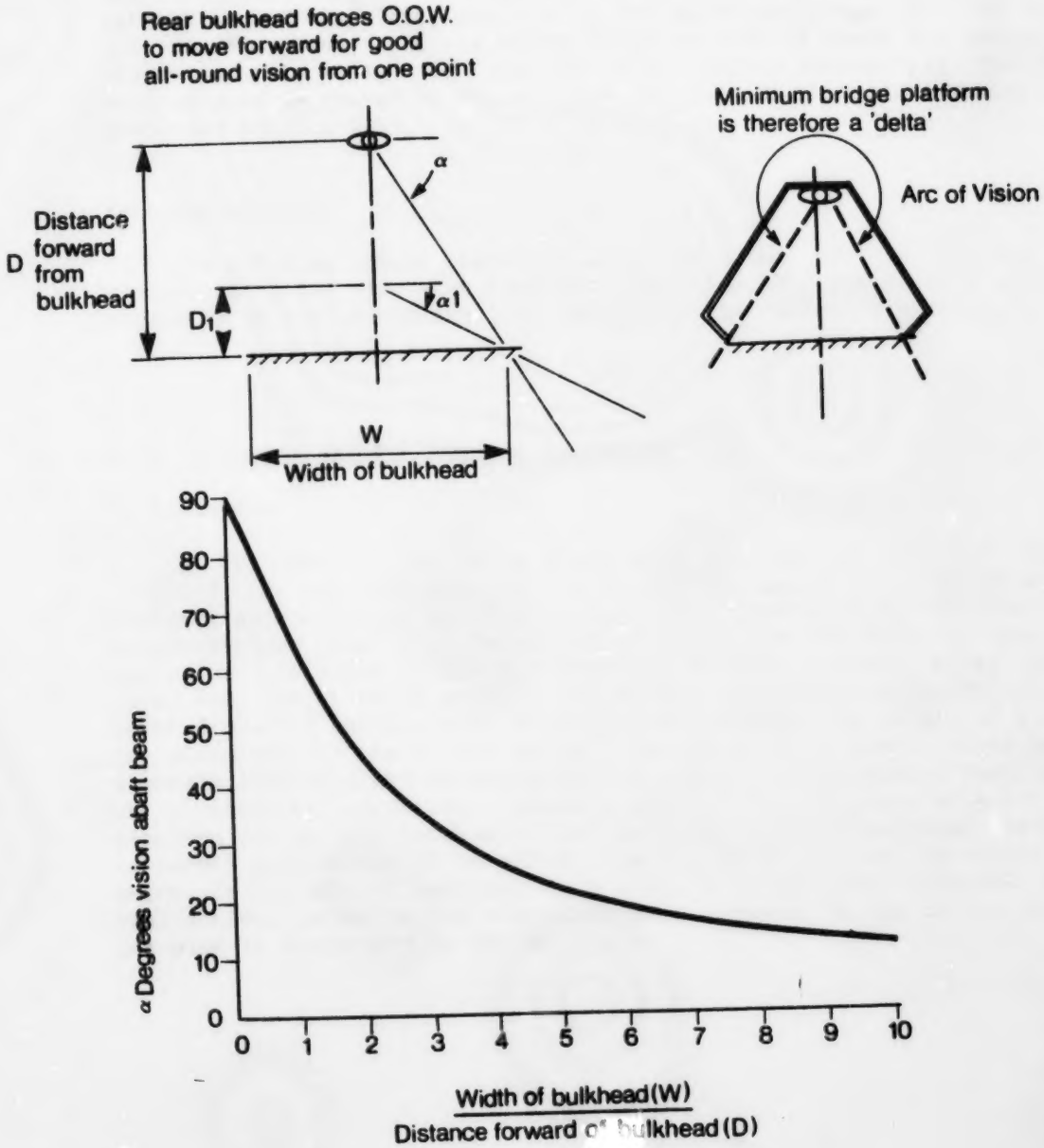
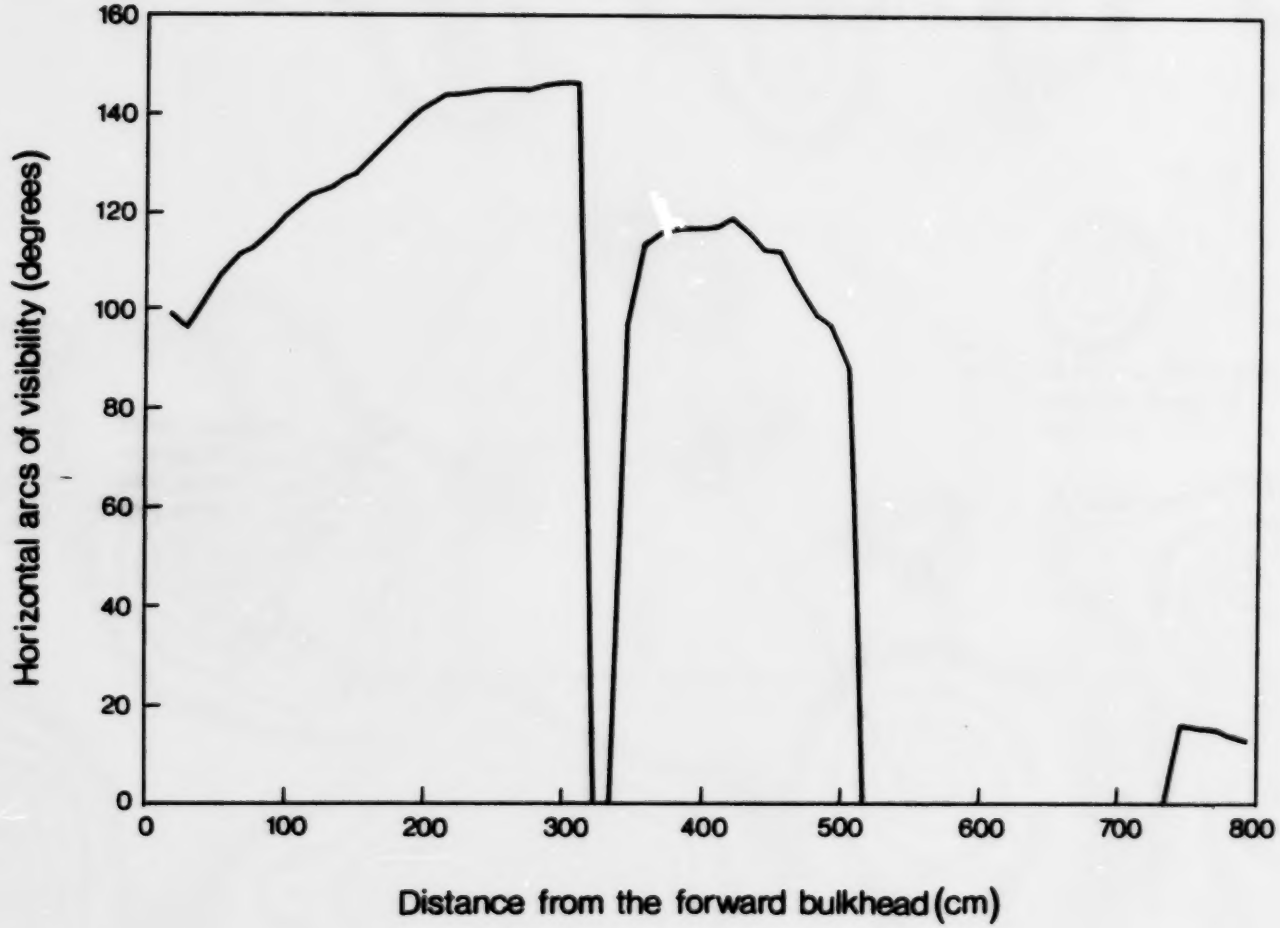


FIGURE 7

Arcs of visibility available along the centre determined for 35 windows

All around visibility



Observations:

Fig. 7 illustrates the effect of moving ahead of the aft bulkhead (chartroom) on visibility. The position where the visibility peaks, just forward of the stanchion (at 3300 mm), corresponds to a width:depth ratio of 1.75 with a potential 280 deg. of horizontal visibility. (In practice this degree of visibility cannot be obtained due to obstructions such as mullions and limited numbers of windows along certain bulkheads. The largest arc of visibility measured on the existing bridge is 146 deg.) The position where the visibility drops to zero is where the centreline stanchion is located. The reduction of visibility approaching the forward windows is caused by the mullions cutting off the view from the windows (see Section 2.5).

Recommendations:

The existing DDH280 chartroom should be moved aft to improve the horizontal field of view from the centreline. The OOW conning position should be on the centreline just forward of the central stanchion.

2.5. Effect of Bridge Shape on Visibility

Requirements:

a. The need for the OOW to stand well forward of the aft bridge bulkhead is one rationale for the "delta" bridge of the older CF ships. However, such a bridge planform suffers badly from wooding in the rear quarters (see Fig. 8). The effect of wooding on the field of view from any point within the bridge is a function of the mullion size, window size and the viewing angle to the window. Given that strength requirements dictate a certain size of mullion and window, the effect of wooding is minimized if the window can be arranged to be as nearly plane to the viewer's line of sight as possible. The 'ideal' bridge shape, then, would be a circular structure. However, much of the advantage of a circular planform can be lost because of the increased width of mullions required to permit each window to be offset from the other windows. As others have shown, in the case of merchant ships (14), a bridge with straight sides can achieve close to the visibility of a circular bridge if the windows are wide in comparison to the mullions.

FIGURE 8

Improvement in visibility offered by octagonal bridge planform, in comparison with delta

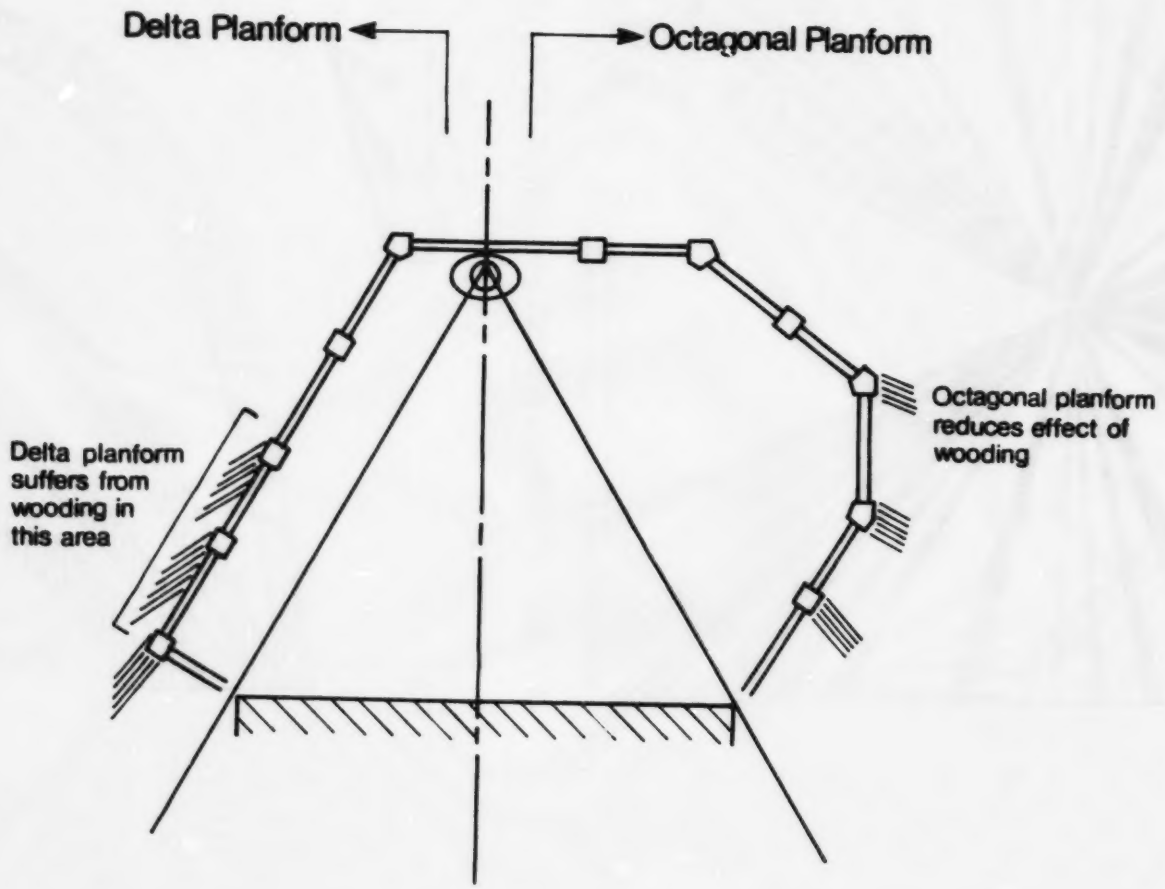
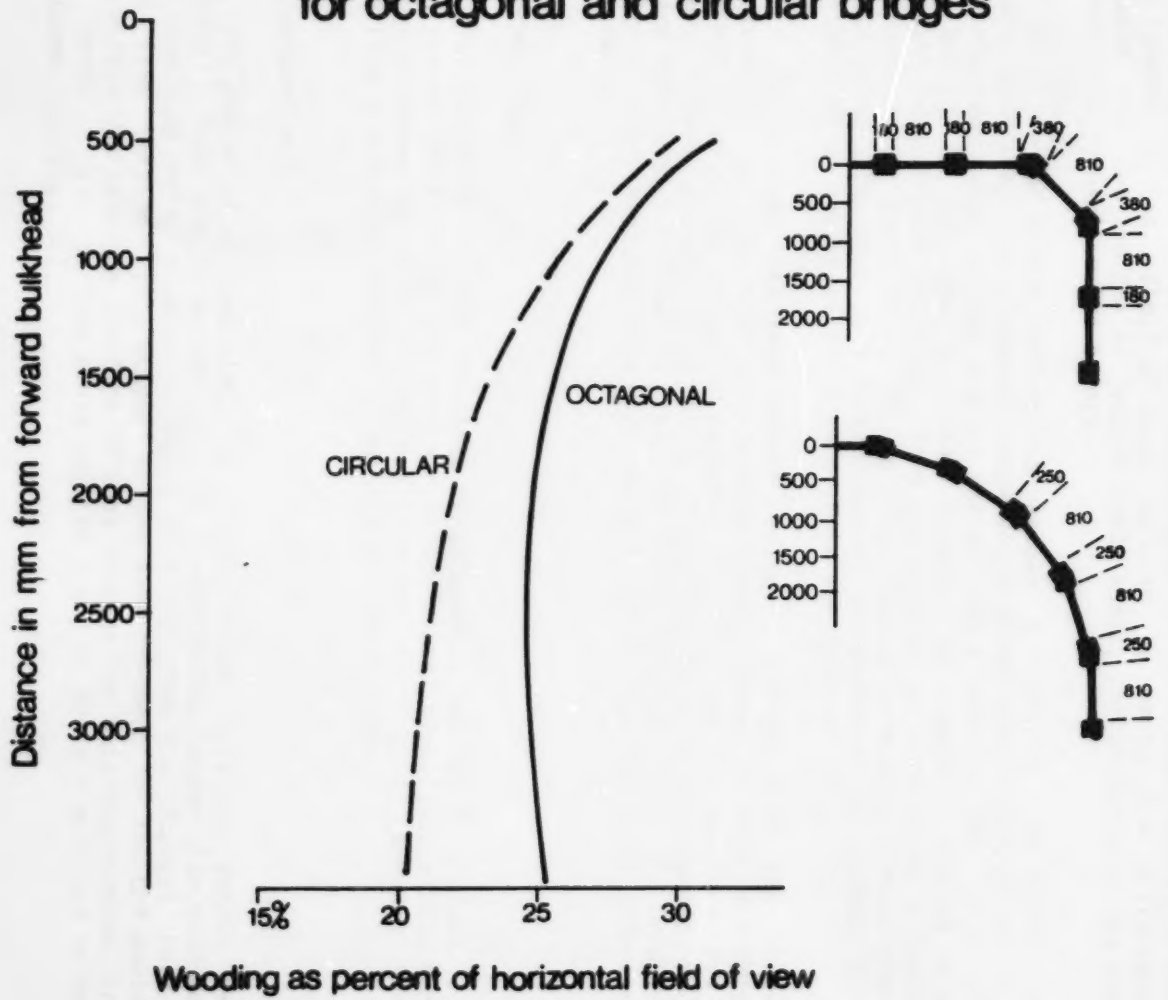

Delta Planform
Octagonal Planform
Delta planform suffers from wooding in this area
Octagonal planform reduces effect of wooding

FIGURE 9

Percent of wooding in forward 180 degree field of view for octagonal and circular bridges



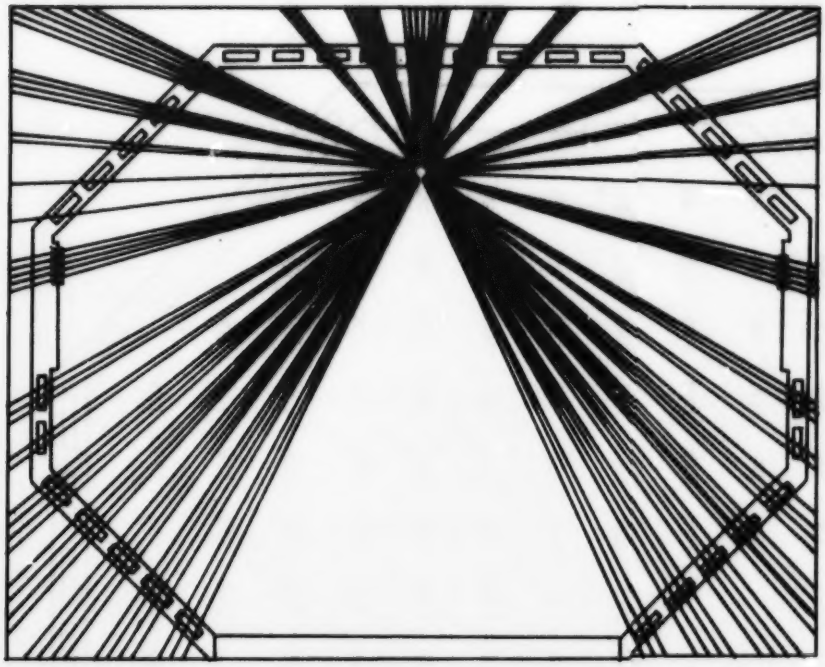


FIGURE 10a Arcs of visibility from a centreline pelorus

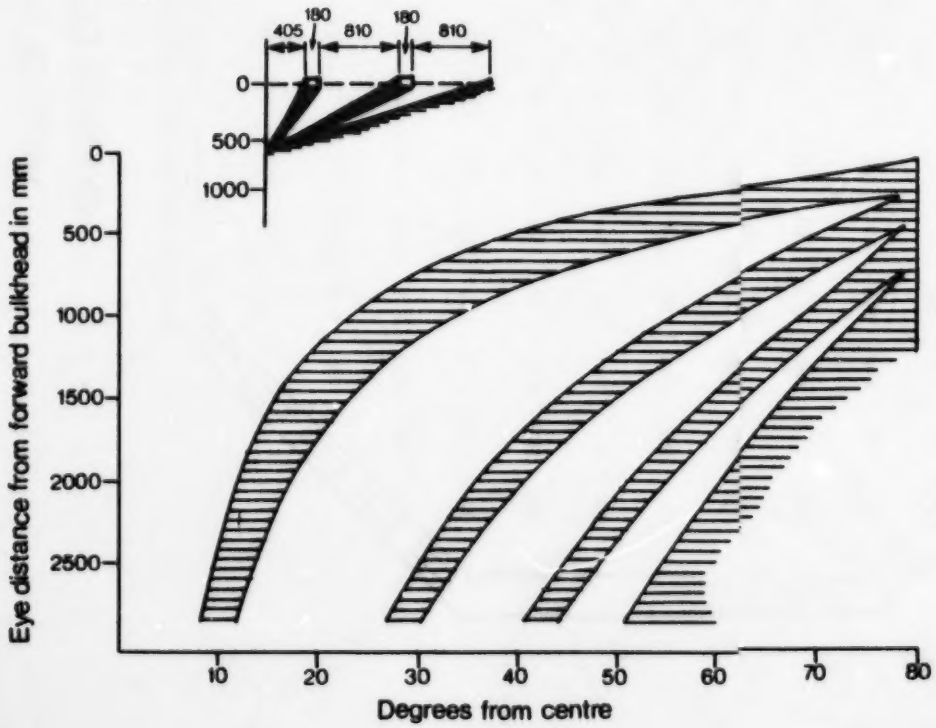


FIGURE 10b Effect of wooding on horizontal field of view with increasing distance from window

b. In warship bridges, however, the ratio of window to mullion width is small (typically 4:1 or less). Figure 9 shows the results of an analysis of the difference in visibility provided by circular and octagonal bridge layouts at different positions along the bridge centreline for the forward 180 deg. field of view. As can be seen, the difference between the two designs is comparatively small, particularly if the OOW stands well forward in the bridge.

c. Given the slight differences between a circular and octagonal bridge planform, the octagonal shape would appear the preferred choice. In fact, many modern bridge designs employ such a layout. The shape of the bridge is not the only issue however. The number of windows in a straight line is also critical. From analyses of the cumulative effects of wooding on visibility, it is clear that no more than five windows should be in line. This is a consequence of the decrease in visual arc through windows progressively further from the observer (Fig. 10).

d. It is clear that many modern bridges conform with the above requirements in that they have no more than 5 windows in line, and they approach an octagonal shape (RN Leander, Type 22, Type 42, Standard Frigate). Others deviate from these principles in being rectangular, and having more than 5 windows in line (USN DD963, British Type 24 Frigate Design). The visibility from such designs can be expected to be inferior to others.

Observations:

The bridge of the DDH 280 class is octagonal, but has 9 windows in line across the front of the bridge. The horizontal visibility within the bridge decreases close to the windows as shown in Fig. 11 because the view from a number of windows is cut off by the mullions.

Recommendations:

The number of windows along the forward bridge bulkhead should be reduced. This can be accomplished by incorporating larger size windows and inserting corner windows at angles 22.5 deg. from the forward bulkhead (see Section 2.6). Windows of the size proposed for the CPF would fit within the existing planform if they replace the existing windows in the ratio 2 for 3. This would require 2 out of every 4 mullions to be replaced.(see Fig. 12).

FIGURE 11

Arcs of visibility in the existing DDH 280 bridge

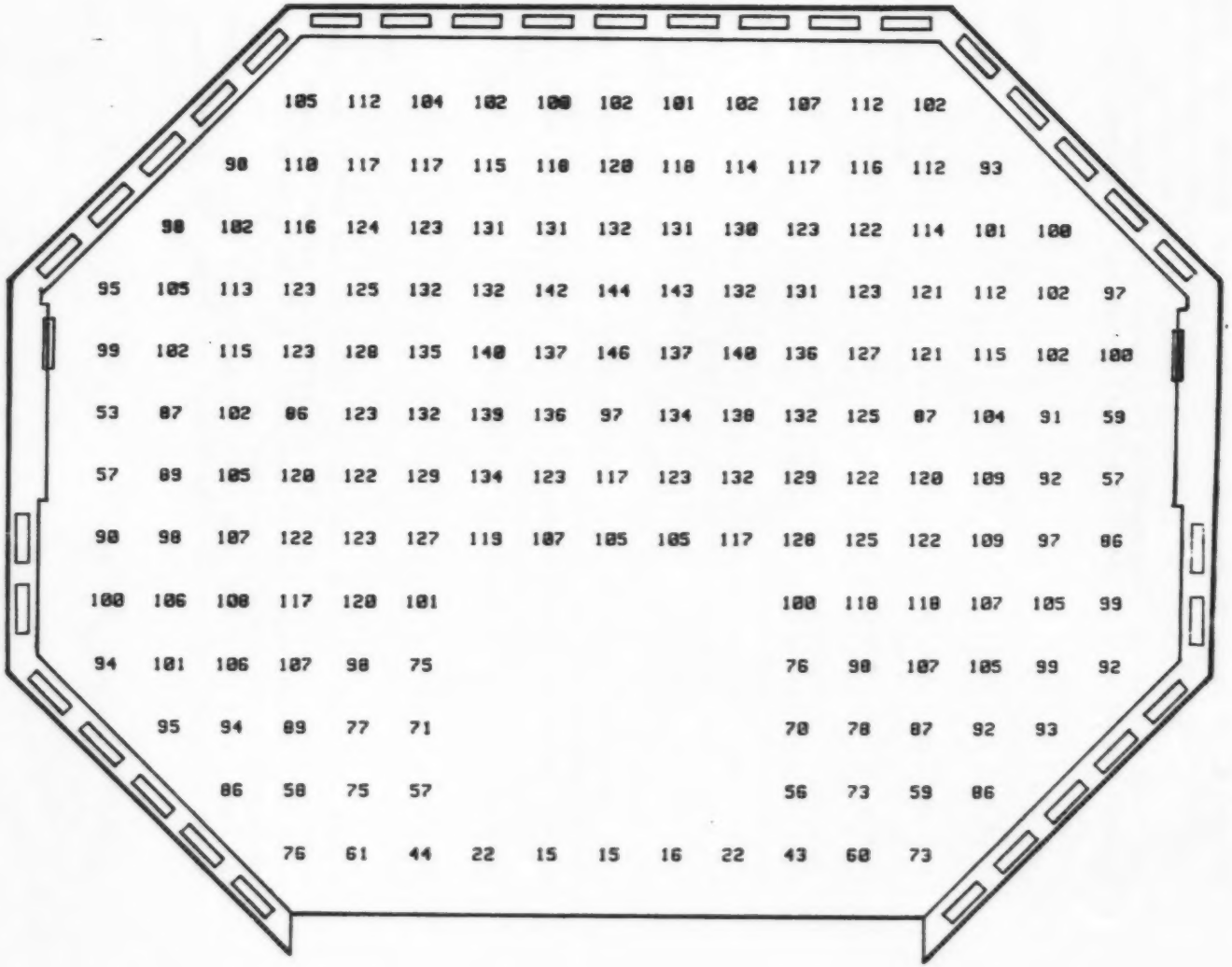
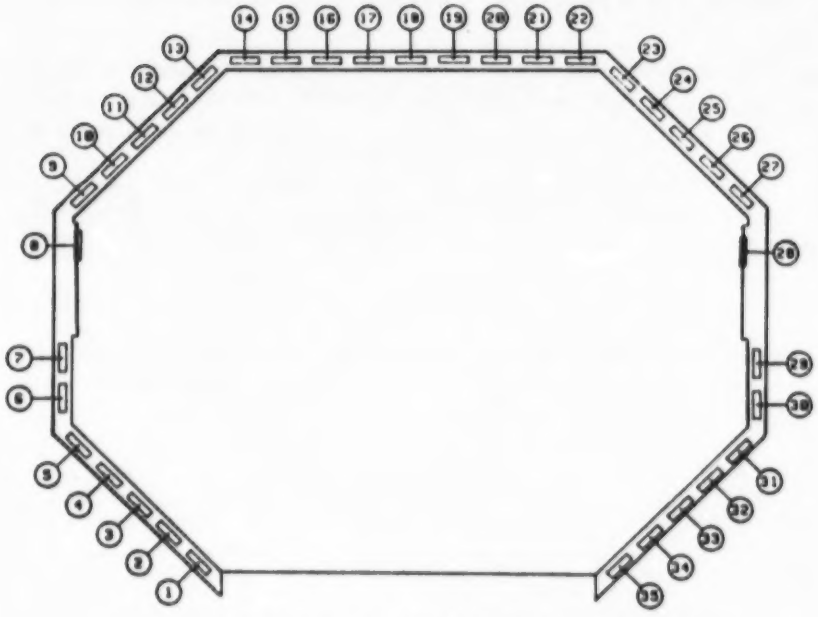
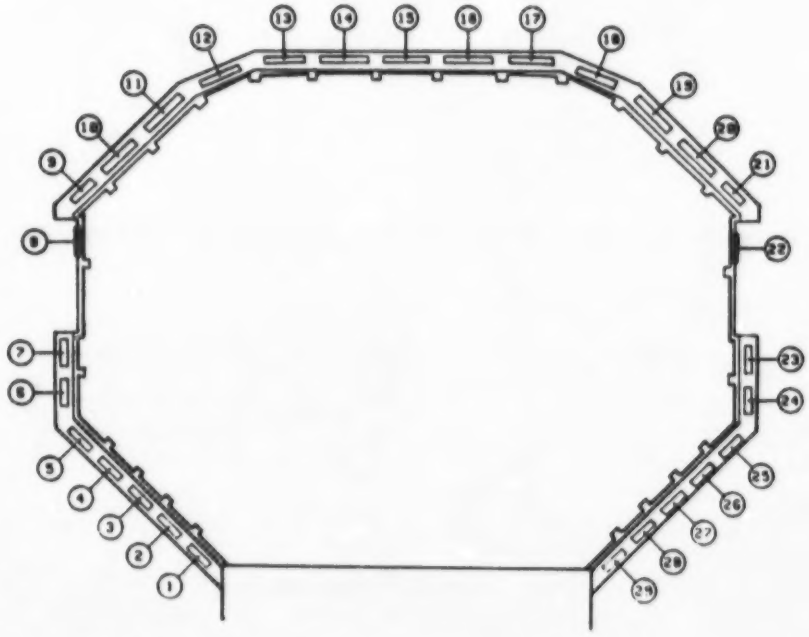


FIGURE 12

Alternative window layouts



Window layout for existing DDH 280 bridge - 35 windows



Window layout proposal for DDH 280 bridge - 29 windows

In January 1984, the DDH280 Bridge Design Committee (15) established priorities for window replacement. The suggested ranking, in decreasing order of importance was as follows:

- installation of the corner windows;
- replacement of the three side windows with two larger windows;
- replacement of the seven forward windows by five larger windows.

2.6. Window Size

Requirements:

a. It is important that the size of both windows and mullions be jointly considered, since improvements in one can be easily offset by deficiencies in the other. The Netherlands Maritime Institute (16) states that T-shaped mullions approximately 200 mm (8 in) wide by 100 mm (4 in) deep have been found by practical experience to be acceptable in merchant vessels. This size of mullion is recommended by NSRC in conjunction with windows a minimum of 800 X 800 mm (31 X 31 in). This combination provides a mullion:window width ratio of 1:4 and a horizontal cut-off angle of 83 1/2 deg. The horizontal cut-off angle dictates the distance back from the front bulkhead at which the depth of the mullion completely obscures the adjacent window (see Fig. 13a). In this case it is 56 mm.

b. The windows of the RN Leander class and the RNlN Standard Frigate, which are stressed to +1 to -0.13 bar (+15 to -5 psi) measure 559 mm high by 864 mm wide (22 X 34 in). It has been shown that even larger windows would be acceptable in warships. Experiments have shown that windows up to 1200 mm (4 ft) square can withstand 19 psi free air overpressure (17).

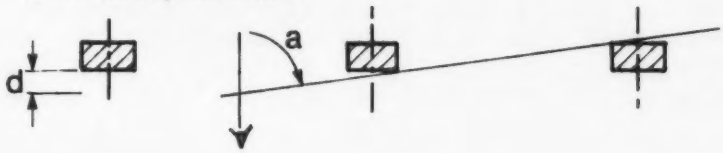
Observations:

The windows fitted in the DDH280 bridge are smaller than the state-of-the-art permits, and in conjunction with large mullions they create a significant wooding problem. Fig. 13b displays the increase in the horizontal arc of visibility that is acquired when smaller mullions and larger windows are used. Both window size and mullion size must be jointly considered if visibility from within the bridge is to be maximized.

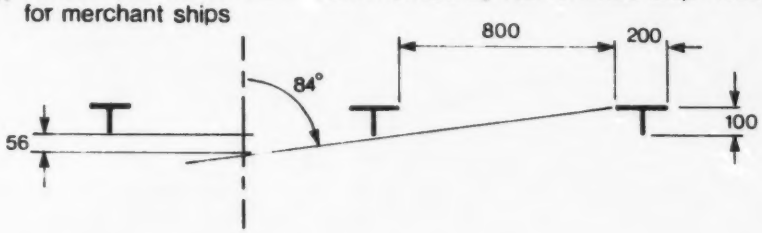
FIGURE 13a

Effect of mullion and window size of field of view in horizontal plane

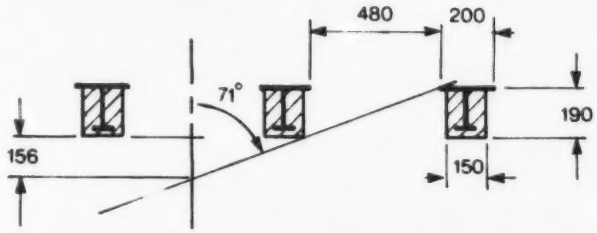
i Width of windows, and sizes of mullions dictate horizontal cut-off angle **a** and distance **d** from bulkhead at which the next window, port and starboard, is completely obscured.



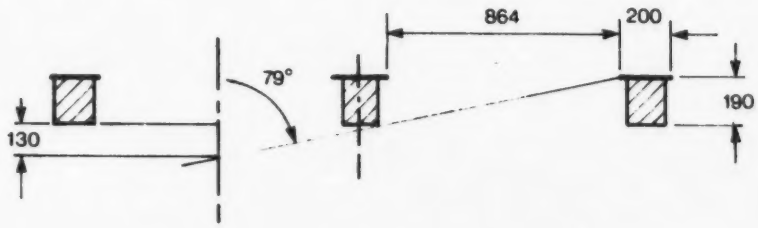
ii Window and mullion sizes recommended by Netherlands Ship Research Centre for merchant ships



iii Window and mullion sizes of DDH 280 class



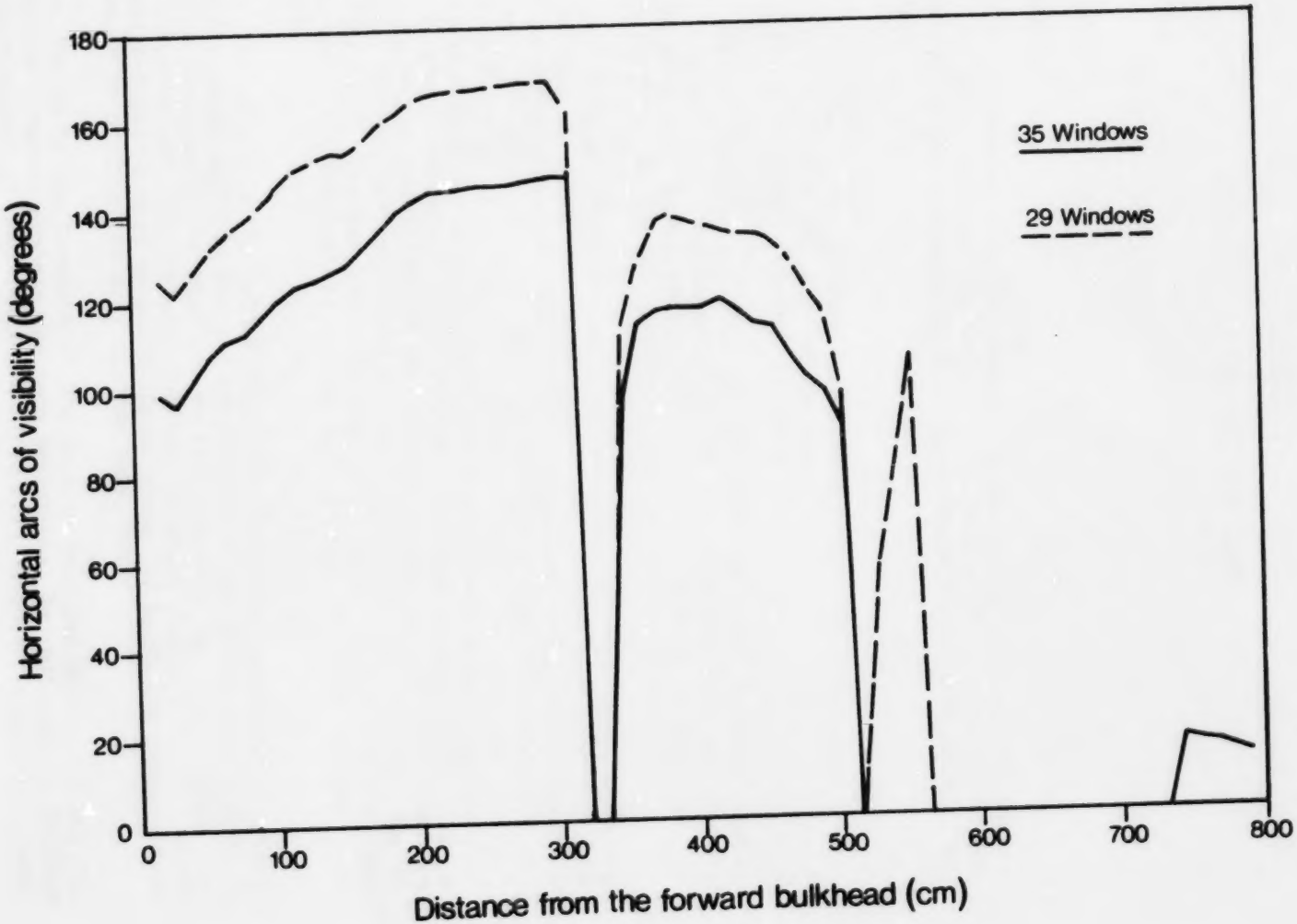
iv Window size from Leander class frigate, and DDH 280 class mullions



All dimensions in mm

FIGURE 13b

Visibility from different sized windows



Specifically, the mullions of the DDH 280 class are some 200 mm wide by 190 mm deep (9 X 7 in) including a 130 X 180 mm rectangular support, and the windows, which appear to be based on those of older CF ships, are 680 mm high by 480 mm wide (27 X 19 in). This gives a mullion:window ratio of 1:2.4, and a horizontal cut-off angle of 71 deg. Thus the mullion obscures the adjacent window from 156 mm away from the bulkhead (see Fig. 13).

The size of the mullions on the DDH 280 class is increased significantly by the insulation applied to the I-beam pillars, which appear to be only 100 X 140 mm (4 X 5.5 in) without the insulation. Smaller mullions than those installed in the DDH 280 are therefore, quite feasible.

Recommendations:

The windows fitted should be a minimum of 635 mm high by 864 mm wide (as recommended for the CPF bridge). This represents an increase of 66% in area over the 280 class windows. If such windows were fitted in mullions of the same size as those of the 280 class, the mullion:window ratio would increase from 1:2.4 to 1:4.3 and the horizontal cut-off angle from 71 deg. to 79 deg.; the distance from a front window at which the adjacent windows are obscured would be reduced from 156 to 130 mm.

Decreases in mullion size would increase the visibility further. The thickness of insulation around the mullions should therefore be reduced.

CHAPTER 3

VISIBILITY IN THE VERTICAL PLANE

3.1. General

Requirements:

a. In conjunction with improvements in horizontal visibility, implications on the vertical field of view must also be considered. The requirements for the vertical field of view can be broken down into four categories:

i. view overhead;
ii. view to sea surface immediately around the ship;
iii. view down the side of the ship;
iv. view to the foredeck of the ship.

b. Fig. 4, Section 2.3 illustrates the vertical viewing angles through typical bridge windows for different distances from the window. It can be seen that upward and downward viewing angles of 10 deg. to 30 deg. are possible if the OOW is within 2 m (78 in) of the window.

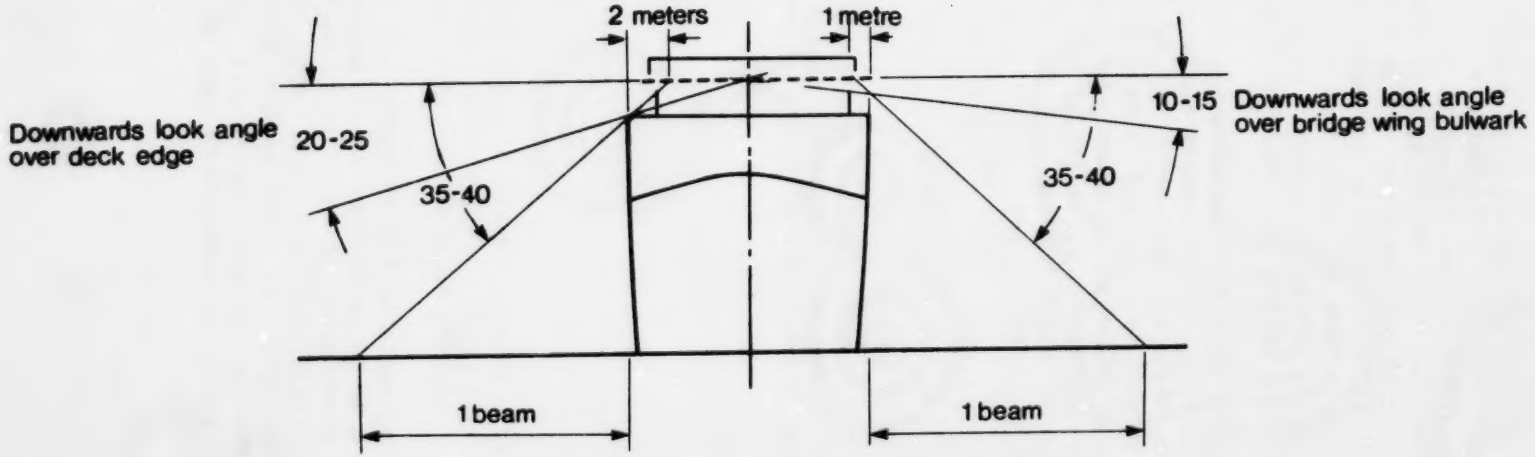
c. For visibility of the sea's surface ahead of the ship, it has been established that the stem should not obscure more than two ship lengths as viewed from the main bridge workstation (18). This distance corresponds roughly to the minimum distance within which the ship can respond to avoid an object directly ahead. Vision to the sea surface immediately around the ship is important during close quarter manoeuvres, pilotage, etc. The best view is available from the bridge wings, but a good view of the immediate sea surface should also be available from the centreline conning position. Again, Fig. 4 indicates what viewing angles are obtainable. It can be appreciated that vision from the bridge centreline will be restricted unless the bridge is very narrow (see Fig. 14).

d. The height of the bridge above the waterline requires a steep downward viewing angle to see the sea surface close to the ship's side. A view down the side of the ship can be obtained only by overlooking the wing bulwarks of the bridge. However, on ships fitted with full width enclosed bridges it must be accomplished either by providing opening side windows or by canting the side windows outwards.

e. Vision to the foredeck of the ship is required by the OOW and XO, to monitor weapon systems and deck evolutions. As indicated in Section 2.3 vision almost 90 deg. below the horizontal is possible if the viewer stands as close as possible to the window.

FIGURE 14

Typical viewing angles in the vertical plane athwart the ship



Bow Elevation

Observations:

The DDH280 bridge was not designed to provide a good vertical field of view. When sailing with a heel due to a beam wind or when in a turn, it is impossible to look across the bridge and see the horizon because it is above or below the window on the far side. The ship is heeled only 4 deg. when the horizon is obscured to the OOW standing on the centreline (2 deg. of heel if he is viewing from one side of the bridge to the other). This problem is due to a combination of the width of the bridge and the window height above deck (see Section 3.2).

The most critical requirements are those dictated by close-quarter manoeuvres. In these circumstances the bridge wings can provide good visibility in the vertical field of view but only on one side of the ship.

Recommendations:

Only the bridge wings provide good visibility to the foredeck and the sea surface within 15 metres of the ship. It is recommended that the communications and ship control displays be added to the wings to permit the OOW to carry out ship handling and ship manoeuvres safely from the wings.

3.2. Window Height

Requirements:

a. Several specifications have been established (19) which relate to window height. These include:

i. View ahead of the ship;
ii. View abeam of the ship;
iii. Minimum window height.

b. From any position on the centreline in the forward bridge, the view forward should include the horizon dead ahead and at least 6 deg. of sea surface below the horizon.

c. From any position on the centreline in the forward bridge, the view across the bridge wings should include the horizon and at least 4 deg. of sea surface below the horizon.

d. The lower edge of the forward windows should be at least 1.2 metres above the deck. The upper edge of the forward windows should be at least 2 metres above the deck.

Observations:

One of the greatest criticisms relating to the visibility within the DDH280 bridge has been the low windows (20). The upper edge of the windows is only 1.86 metres, well below the 2.0 metres requirement. In the worst case, the present window heights (lower edge 1.21 metres and upper edge 1.86 metres) permit a view of the sea's surface only as close as 65 metres ahead and 185 metres abeam for an operator of 5%ile standing eye height at the centreline. In the best case, the same window heights permit a view of the sea's surface as close as 60 metres ahead and 25 metres abeam for 95%ile eye height at a position just behind the windows.

Elevation of the window height would do little to improve the visibility close to the ship because the major limitations are imposed by the heights of the wing bulwarks and the ship's bow. Moreover, higher windows would reduce the visibility close to the ship for shorter individuals. This has particular importance for operations conducted using the centreline pelorus. The maximum pelorus height still permitting use by men with 5%ile eye height is about 1490 mm. (see Section 4.6). Elevation of the window height would seriously reduce the utility of the centreline pelorus for sighting objects close to the ship.

Recommendations:

It is recommended that the window height remain at 1210 mm. (Note that removal of the forward bridge platform should reduce the requirement for the taller bridge officers to slouch or bend down to see through the windows.)

3.3. Window Slope

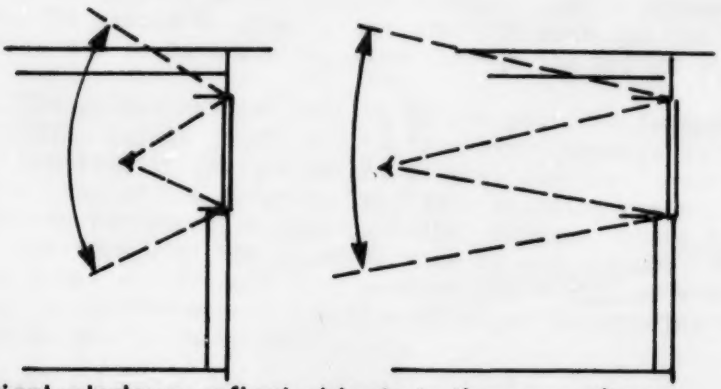
Requirements:

a. In many bridges, reflections of bright objects within the bridge can be seen in the windows, particularly at night. To reduce the incidence of such reflections, windows should be sloped.

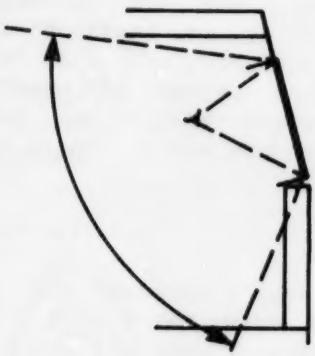
b. It is important that the effect of window slope be understood. A sheet of glass used as a window can be considered to be a plane reflecting mirror, and it will reflect light from the observer's side of the glass into the observer's eyes (see Fig. 15i, 15ii). Normally such reflections are not perceptible because there is little contrast with the view seen through the window. Very bright objects, or lighted objects in an otherwise dark room will be seen as reflections in the windows.

FIGURE 15

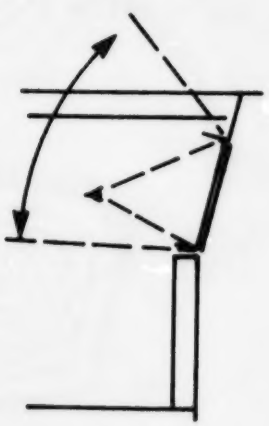
Use of window slope to control reflections



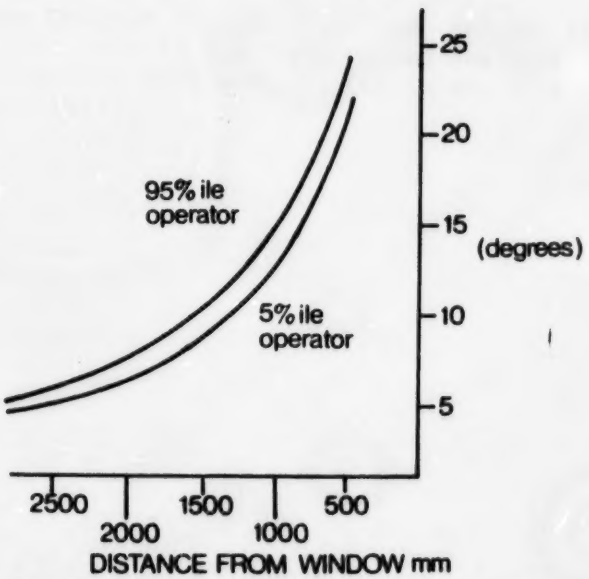
i · Vertical windows reflect objects in the arcs shown
· Arcs change with viewing distance



ii 'Rearwards' or 'inwards' sloping windows reflect objects in a larger arc, including the deck



iii 'Forwards' sloping windows reflect from waist-height upwards



Plot of window angle needed to reflect only higher than the bottom of the window

c. If the window is angled in the vertical plane it will reflect the image of either the deck, or the deckhead, into the observer's eyes. Bridge windows angled backward such as car or aircraft windscreens would reflect the deck and objects below the eyes of the observer (see Fig. 15ii). Windows angled forward such as modern ships' windows, will tend to reflect the deckhead and objects above the eye of the observer.

d. Reflections in the windows can be avoided by inclining the windows forward, provided the brightness of the bridge deckhead can be controlled. The deckhead should be painted a mid-reflective grey, for daytime use, and have shielded lights for use at night. The amount of deckhead light that is reflected in the window will depend on the window size, deckhead height, and observer to window distance. Fig. 15iii shows the results of an analysis of the window slope required to avoid reflecting from objects above waist height, with increasing distance from the window.

e. From Fig. 15iii it can be seen that the field of view of an observer standing close to a window (within 1 metre) is so great (40 deg. plus) that no amount of window slope can prevent objects at about waist height (e.g. lights on a console) from being reflected in the window. Therefore, all lights and bright components close to the window must be shielded to avoid reflections to the observer standing close to the window. (For lighted consoles this is invariably done by having the most forward face of each console set parallel to the nearest window so that the direct path of light is blocked.)

Observations:

Angling windows in the vertical plane has proved an effective means of controlling reflection, if implemented in conjunction with a properly designed equipment, lighting system and a mid-reflectance gray deckhead finish.

The windows of the DDH 280 class are inclined outwards at 10 deg. in order to control such reflections. Although this angle is recommended by some authorities, a 15 deg. slope is considered more effective.

Recommendations:

Given that the angle of the window cannot be easily changed, particular attention should be paid to shielding lights and other sources of reflection, especially on those consoles closer than 1500 mm to the windows.

3.4. Console Height

Requirements:

a. Each console's height should permit the operator to see the OOW so that face-to-face communication with the OOW is accommodated. In addition the OOW should be able to see over all consoles to monitor bridge activities and to have a clear view through the bridge windows.

b. The guidelines for console height provided in documents such as MIL-STD-1472 assume that for a 'see-over' console sufficient field of view is provided if the eye height of the 'shortest' operator is in line with the top of the console. The 5%ile standing eye height, 1510 mm, is not adequate for consoles used on ships' bridges, where it is important not to interfere with the field of view to any windows. The approach outlined by Hanna and Ireland (21) permits the design of a true 'see over' console, with the operator's line of sight determining the maximum permissible height of the console.

c. As shown in Fig. 16, consoles placed close to windows should be sized so that the height is just less than the height of the bottom of the window. Consoles and equipment located inboard of windows should be sized so that the height does not intrude into the line of sight of the OOW or others who may be standing some distance from the console, looking over it. The simplest case is that shown, where the console is midway between the observer and the window. The height of the console should then lay midway between the height of the bottom of the window and the eye height of the shortest likely observer.

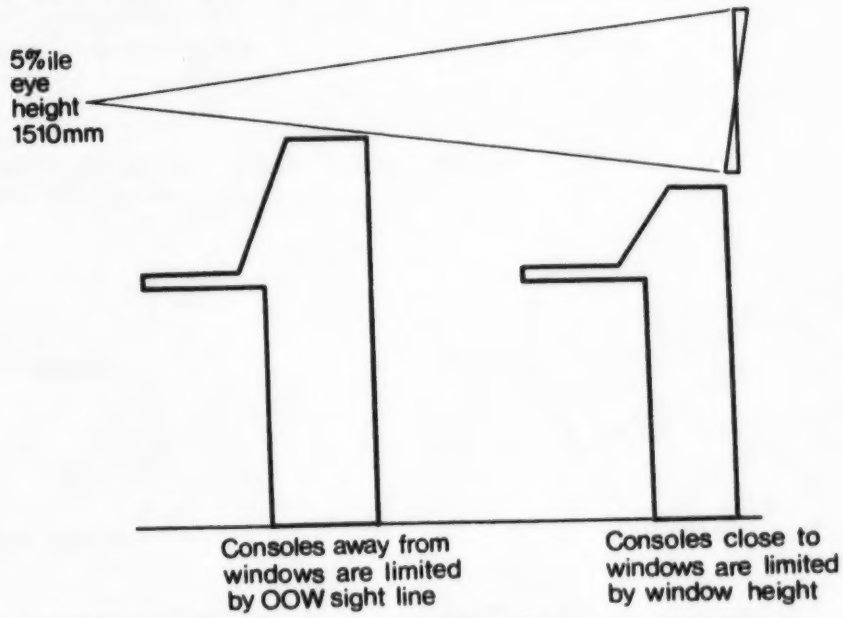
Observations:

The combined height of the Helmsman's console and the bridge platform interferes with the OOW's view to the foredeck and sea's surface close to the bow. This is particularly true when the OOW is standing at a position aft of the bridge platform.

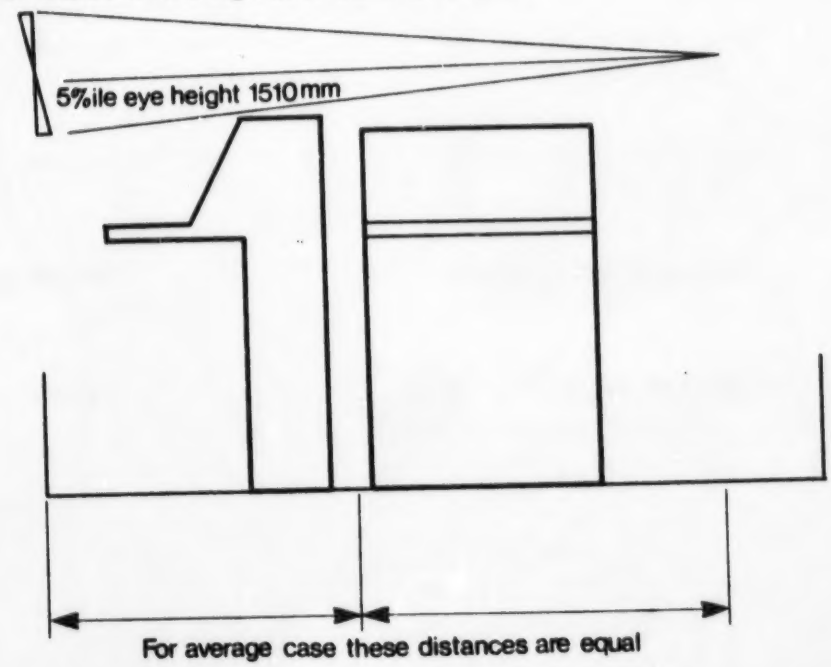
FIGURE 16

Limitations on console height

a. OOW standing aft looking forward



b. OOW standing forward looking aft



Recommendations:

Removal of the forward bridge platform and movement of the consoles aft by 770 mm to provide passage along the windows as recommended in the bridge layout study (2) should alleviate the problem. Using the height of the lower edge of the window (1210 mm) and 5%ile standing eye height (1510 mm), these consoles should be no higher than 1320 mm (52 in).

3.5. Seat Height

Requirements:

a. Sit/stand seats are particularly suited to use on ships' bridges. This term applies to seats which maintain the eye height of operators at, or close to, their standing eye height. Such seats offer the advantages of permitting seated operators the same view as standing operators, and, if on rails or slides, permitting an operator to use a console when either seated or standing. These seats should be provided for Command, OOW and Squadron Commander. Other operators such as Communicators and Bosun's Mate can be provided with normal seats because they do not require a good outside view. (This is standard practice in the RN).

b. Seats which maintain the operators' standing eye height exactly are difficult to use. The operators are required to lift themselves up in order to be comfortably seated. It is, therefore, preferable to adjust the height of these seats so that the operator's eye height is slightly below the standing 5%ile eye height. The seat heights recommended in MIL-STD-1472 are 695 $\pm$ 75 mm. Representative eye heights would then be:

	5%ile	95%ile
Seat height	770 mm	620 mm
Eye height above seat	720 mm	846 mm
Seated eye height	1490 mm	1466 mm
Standing eye height	1510 mm	1730 mm

A footrest must be provided for sit-stand seats, built either into the base of the chair or into the base of the console.

Observations:

The view available from the seated position is generally poor, particularly for the Helmsman.

TABLE 1
RECOMMENDED SEAT DIMENSIONS

Seat height - normal seats (to compressed forward edge)	380 mm - 430 mm
Seat height - sit/stand seats (to compressed forward edge)	620 mm - 770 mm
Seat width	510 mm
Between armrests	500 mm
Seat length	430 mm
Seat squab angle	0^{o} - 5^{o} to horizontal
Seat back angle	100^{o} - 115^{o} to horizontal
Backrest height	380 mm above rear edge of seat squab
Armrest height	220 mm above rear edge of seat squab
Footrest height	405 mm below mean seat height
Footrest angle	0^{o} - 5^{o} above horizontal

Recommendations:

The seats provided on the bridge should conform to human engineering criteria such as those outlined in Ref. 22, 23, 24. The basic dimensions for seats are outlined in Table 1.

The Commanding Officer, Squadron Commander and others requiring a good outside view should be provided with sit-stand chairs which maintain their standing eye height when seated.

The Helmsman should be provided with a seat high enough to permit him to see the horizon.

The OOW should be provided with a seat that can be easily set up and stowed either at the OOW console or the centreline conning position.

CHAPTER 4

VISIBILITY IN WORKSTATION DESIGN

4.1. Command/OOW Workstation

Requirements:

a. The operational requirement for particularly good visibility ahead of the ship demands that the command console be placed forward in the bridge.

b. The minimum acceptable visibility for the Commanding Officer and Officer of the Watch at this workstation extends over an arc from 22.5 deg. abaft the beam on one side forward to 22.5 deg. abaft the beam on the other side. The give-way obligations between power driven vessels in the crossing situation make the visibility to the starboard quarter more critical than that to the port quarter. Therefore, this workstation should be placed on the centreline or just to starboard.

c. From a position just behind the CO/OOW console, a view from the horizon to the stem of the ship should be available. Preferably, this position would also offer a view of the foredeck to permit surveillance of deck evolutions.

Observations:

An observer on the centreline is required to stand 156 mm aft of the forward window to view through the windows immediately to port or starboard of the centreline (see Section 2.5). In order to see through the other windows along the same bulkhead he must stand an additional 156 mm aft for each window further port or starboard. (For the proposed window layout this distance is reduced to 130 mm.) Therefore, if the CO/OOW console is centred behind window 20 in the existing window layout the after edge of the console should be at least 1090 mm aft of the forward bulkhead. (The after edge of the console need be only 390 mm for the console centred behind window 16 in the proposed window layout.)

In the DDH280 bridge the line of sight from the bottom edge of the window to the stem is 8 deg. This requires the eye height of an observer behind the console to be raised an additional 140 mm above the 1210 mm window height for every meter he is aft of the bridge windows in order to see the stem. Therefore, an operator with a 5%ile standing eye height (1510 mm) can be no further than 2 metres aft of the windows. Similarly, the distance from the after edge of the CO/OOW console to the window should be no more than 2 metres.

Recommendations For OOW/Command Workstation:

CONSOLE	- sit-stand profile; - height not greater than 1320 mm.
SEATING	- sit-stand, fold-away seat.
LOCATION	- forward bridge area, starboard; - forward edge of console 770 mm aft of forward bulkhead; - after edge of console no more than 2000 mm aft of forward bulkhead; - within 2 metres of centreline pelorus and Helmsman.
FIELD OF VIEW	- facing forward; - external vision as per Section 2.1 .
ACCESS	- good access to bridge wings, forward windows; - OOW/CO must be able to overlook conning displays, sensor & status displays.

4.1.1. Centreline Conning Position

Requirements:

a. The centreline conning position is a feature of the majority of naval bridges. This position is the principal one from which the ship is conned, except in those circumstances when improved vision is required along one side of the ship.

b. From the centreline conning position the OOW or Command should therefore have readily available, all displays and controls necessary to con the ship. Such displays and controls cannot all be built into the pelorus stand.

c. The pelorus should be located some distance aft of the forward bulkhead, rather than mounted on the bulkhead (see Sections 2.4, 2.5, 4.6). In this location, there is space available forward of the pelorus for the OOW's and Helmsman's consoles. This permits the OOW to supervise the Helmsman as well as monitor important displays.

Recommendations For Centreline Conning Position:

CONSOLE DESIGN	- pelorus should be comfortable height for use by operator (1490 mm pelorus height will accommodate 5%ile standing eye height); - pelorus height should permit viewing over Helmsman's head if Helmsman is located in the forward bridge.
SEATING	- fold-out seat, easily stowable, aft of pelorus; - sit-stand height.
LOCATION	- 2 metres aft of window (measured from after edge of mullion).
FIELD OF VIEW	- facing forward; - external vision (see Section 2.1).
ACCESS	- ready access to forward windows, and wings; - ready access to chart table and radar; - able to overlook Helmsman's console; - ready access to engine throttles; - ready access to Command console; - able to see deckhead mounted conning displays, sensor displays, combat system status displays.

4.2. Helmsman's Workstation

Requirements:

a. The relationship between the OOW and the Helmsman is vital to the safe operation of the ship. The importance of enabling the OOW to constantly monitor the performance of the Helmsman tends to be downgraded possibly because older ships have the helm located remotely from the bridge . The communication link between Helmsman and the OOW is one more element in the ship control loop, and therefore represents a possible source of error. The most reliable communication link between the Helmsman and the OOW is a direct face to face voice link. This demands that the two be within 2 metres of one another (25).

b. The Helmsman should also be located so that the OOW is able to monitor the Helmsman's displays from either the centreline conning position or the CO/OOW console.

c. The throttles should be placed to port of the wheel so that the Quartermaster does not interfere with the OOW's ability to monitor the Helmsman and take bearings ahead from the centreline pelorus.

d. The only visibility requirements for the Helmsman are in the

sector directly ahead of the ship. A forward view permits the Helmsman to relate the rate of turn seen on the tape repeat with that seen on the horizon, alerting him quickly to a gyro or steering gear failure. In the event of a gyro failure in pilotage waters, good forward visibility permits the OOW to order the helmsman to steer on a distant leadmark. This is particularly important on the DDH280 bridge which lacks a magnetic compass. It relieves the OOW of the requirement to continuously conn the ship. In order to provide the Helmsman a view of the horizon his seated eye height must be higher than 1210 mm - the height of the window ledge.

e. A view of the sea close to the ship is not considered essential for the Helmsman. Indeed, it is perhaps distracting for the Helmsman to see ships and objects close to the ship and this may lead to inappropriate action in key situations.

Recommendations For Helmsman's Workstation:

CONSOLE	- throttle controls on port side to prevent personnel blocking view from centreline pelorus; - height not greater than bottom edge of windows (1210 mm).
SEATING	- seat height sufficient to provide view over console to the horizon; - vertical seat adjustment from 380 to 500 mm in increments no greater than 25 mm.
LOCATION	- forward bridge area, to port of centre; - within 2 metres of centreline conning position and OOW console; - Helmsman centred behind a forward window; - forward edge of console 770 mm aft of forward windows.
FIELD OF VIEW	- facing forward; - view directly forward to the horizon.
ACCESS	- accessible to OOW and Quartermaster

4.3. Navigation Workstation

Requirements:

a. Visual fixing requires good visibility to the beam and quarters as well as ahead of the ship. As this is not generally available from pelori within the DDH280 bridge, the chart table should be placed so that it offers good access to the pelori on the wings.

b. The preferred orientation for the chart table is facing forward. This placement, used in conjunction with a navigational radar display mounted immediately abeam of the chart table enables the radar, chart and visual landmarks to be correlated quickly without ambiguity. This is an advantage for both the Navigation Officer and the OOW. It also permits the chart to be illuminated at night without any of the light spilling over into the forward bridge area, or being reflected in the windows. If the deckhead area is painted a mid-reflectance (50% reflective) shade, a see-over chart table with a backboard 1300 mm above deck can be used without additional shielding or curtains (26).

c. The height of the backboard should not obstruct the view from the centreline pelorus to any of the windows. Therefore, the maximum height of the backboard should be 1390 mm.

Recommendations For Navigation Workstation:

CONSOLE DESIGN	- total height of console including backboard not greater than 1390 mm.
LOCATION	- near athwartship gangway, close to centreline.
FIELD OF VIEW	- facing forward.
ACCESS	- good access to bridge wings, pelori for visual fixing.

4.4. Communicators' Workstation

Requirements:

a. The visibility requirements of the communicators within the bridge are to the flagdeck and bridge wings.

b. The human engineering requirements for the design of this workstation have been outlined (2).

Recommendations For Communicators' Workstation:

CONSOLE DESIGN	- must shield other areas of bridge from light reflected from writing surfaces;
SEATING	- normal height.
LOCATION	- against chartroom bulkhead.
FIELD OF VIEW	- internal bridge, flagdeck and wings.
ACCESS	- accessible to OOW, good access to Command, bridge wings and flagdeck; - frequent access to status board.

4.5. Bosun's Mate's Workstation

Requirements:

a. There are no significant visibility requirements for the Bosun's Mate.

Recommendations For Bosun's Mates Workstation:

CONSOLE DESIGN	- must shield writing light from forward bridge.
SEATING	- sit-stand height.
LOCATION	- against chartroom.
FIELD OF VIEW	- internal bridge and wings.

4.6. Centreline Pelorus Location

Requirements:

a. A centreline pelorus should be provided for use primarily by the OOW for station keeping and collision avoidance. The need for a

centreline pelorus is based on use during manoeuvres with a consort, more than on use for navigation purposes, for which the error incurred by an off-centre pelorus is small. However, use of the centreline pelorus to establish and maintain leadmarks makes it an asset in navigation as well.

b. There is a major difference in the location of the pelorus between different countries. RN ships typify one approach, where the pelorus is located some 2 metres aft of the forward windows; many U.S.N. bridges typify the alternative where the centreline pelorus is mounted on the forward bulkhead. Although a bulkhead mounted pelorus provides excellent visibility over a limited arc (the subtense of the centre window which, in the case of such an installation in the DDH 280 bridge, for example, would be $\pm$ 45 deg.) an island pelorus provides visibility over a much wider arc, but is wooded in some sectors (see Fig. 10, Section 2.5).

c. Visibility is not the only criterion in locating the pelorus. Accessibility is also important. The bulkhead mounted pelorus lends itself to use by the OOW and, when required, by Command, but is inconvenient for the Navigation Officer because he must pass the OOW and/or Command in order to have access to the pelorus. The bulkhead mounted pelorus also interferes with freedom of movement along the windows. The island location, in contrast, is easily accessible by the Navigating Officer as well as Command and OOW.

d. The ability to supervise the Helmsman and monitor the activities at the forward consoles is maintained with an island pelorus position. The height of a centreline pelorus should permit viewing over all consoles (see Section 3.4).

e. For position fixing, a logical complement to the centreline pelorus is closed circuit television for visual coverage of the blind sectors aft of the hanger and flight deck (see Fig. 10a). The camera should be trainable by either the OOW or Navigating Officer, with the true and relative bearings of the camera boresight superimposed on the display. This camera would be in addition to the television camera mentioned in Sec. 2.2, which displays the ship's side and stern.

Observations:

The advantages and disadvantages of the two different pelorus locations are itemized in Table 2. Considering all these factors the island location is preferable, despite the disadvantage of breaks in the field of view caused by wooding.

The optimal location for the centreline pelorus with respect to vertical arcs of visibility should provide a view forward from the ship's stem to the horizon. The location can be determined by aligning the pelorus azimuth with the lower edge of the forward window and the jackstaff. In the DDH280 bridge, the line of sight from the bridge down to the stem is 8 deg. requiring the pelorus to be an additional 140 mm above the 1210 mm window height for every metre the pelorus is aft of the bridge windows. Therefore, at the maximum height compatible with a man's 5%ile standing eye height (1490 mm), the centreline pelorus should be positioned 2.0 meters aft of the forward window to provide a view of the

stem.

The optimal position for the centreline pelorus with respect to horizontal arcs of visibility is dependent upon the bridge window layout chosen. The two window layouts under consideration include: the existing layout of 35 windows each 650 X 495 mm (25.5 X 19.5 in.); and the proposed layout combining 14 forward windows each 635 X 864 mm (25 X 34 in.) with 15 aft windows each 650 X 495 mm (25.5 X 19.5 in.).

For the 35 window layout the optimal position for the centreline pelorus with respect to horizontal arcs of visibility can be determined with reference to Fig. 17. The peak visibilities along the centreline, (143-147 deg.) incorporating the arcs through all 35 bridge windows, occur 2000 to 3200 mm aft of the forward window. The peak visibilities along the centreline, (95-99 deg.) incorporating the arcs through the forward 21 windows only, occur roughly over the same positions.

For the 29 window layout proposed in Section 2.5, the optimal position for the centreline pelorus with respect to horizontal arcs of visibility can be determined with reference to Fig. 18. The peak visibilities along the centreline, (165-168 deg.) incorporating the arcs through all 29 bridge windows, occur 2000 to 3200 mm aft of the forward window. The peak visibilities along the centreline, (116-118 deg.) incorporating the arcs through the forward 15 windows only, occur slightly forward between 1600 and 3000 mm aft of the forward window.

Recommendations:

The optimal location of the centreline pelorus is 2.0 metres aft of the forward window, providing a good panoramic field of view (143 deg. for the existing window layout, 165 deg. for the proposed window layout), and quick access by the Commanding Officer, OOW and Navigating Officer.

TABLE 2

TRADE-OFF TABLE

Issue: Pelorus Mounted on Front Bulkhead
VS
Free-Standing Pelorus

	Bulkhead Mounted Pelorus	Island Mounted Pelorus
Advantages	-easily accessible by OOW;	-easily accessible by Navigating Officer, from chart table, as well as Command/OOW;
	-excellent forward visibility with unbroken arc of view ± 45 deg.	-good panoramic field of view, ± 150 deg.
		-supports centreline conning because Helmsman and displays are easily monitored.
Disadvantages	-poor panoramic vision field of view is approximately ± 45 deg. to ± 60 deg.;	-wooding interferes with panoramic field of view;
	-incompatible with bulkhead mounted consoles;	-field of view through centreline window is restricted;
	-difficult access for Navigating Officer.	

FIGURE 17

Comparison of arcs of visibility along the centreline for 35 windows versus 21 windows

35 WINDOWS (All around visibility) ——

21 WINDOWS (180° visibility) · · · · · · · ·

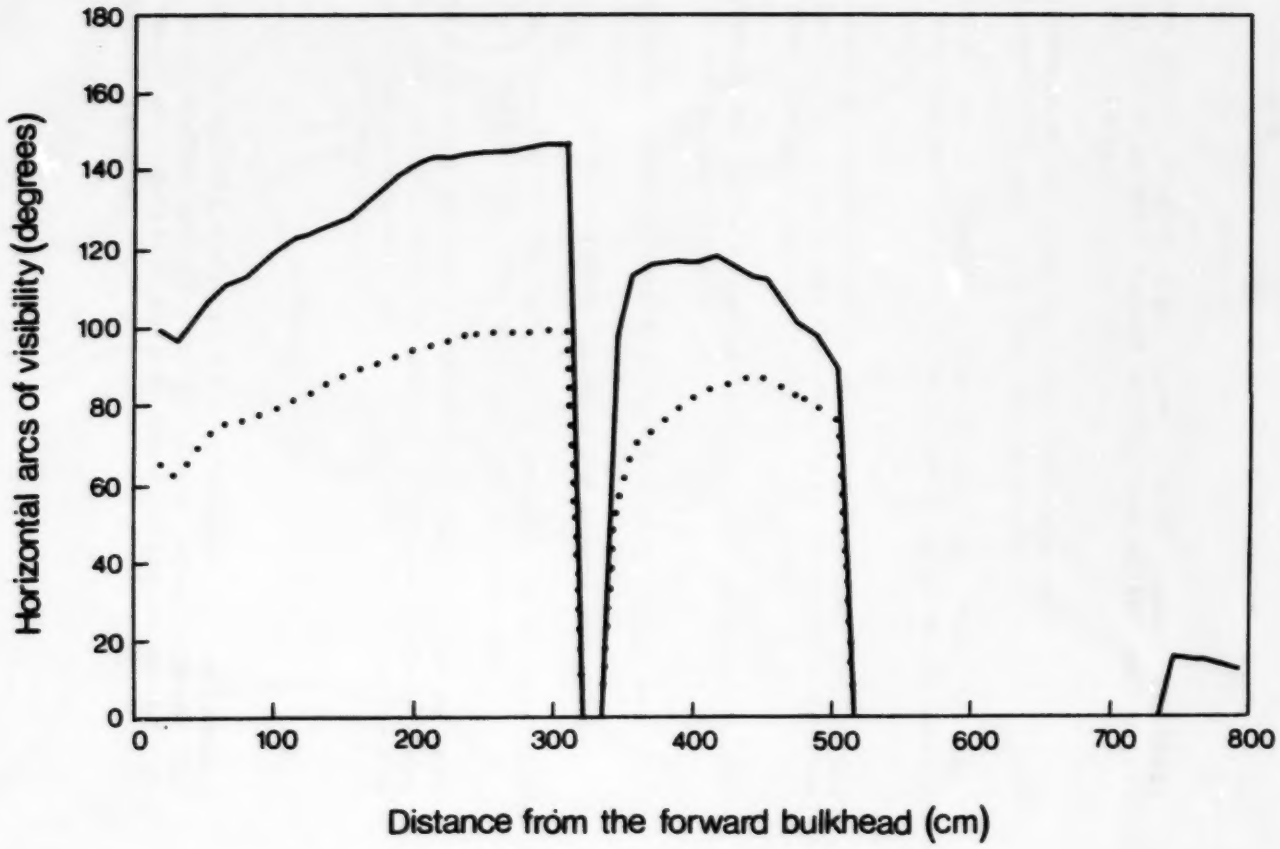
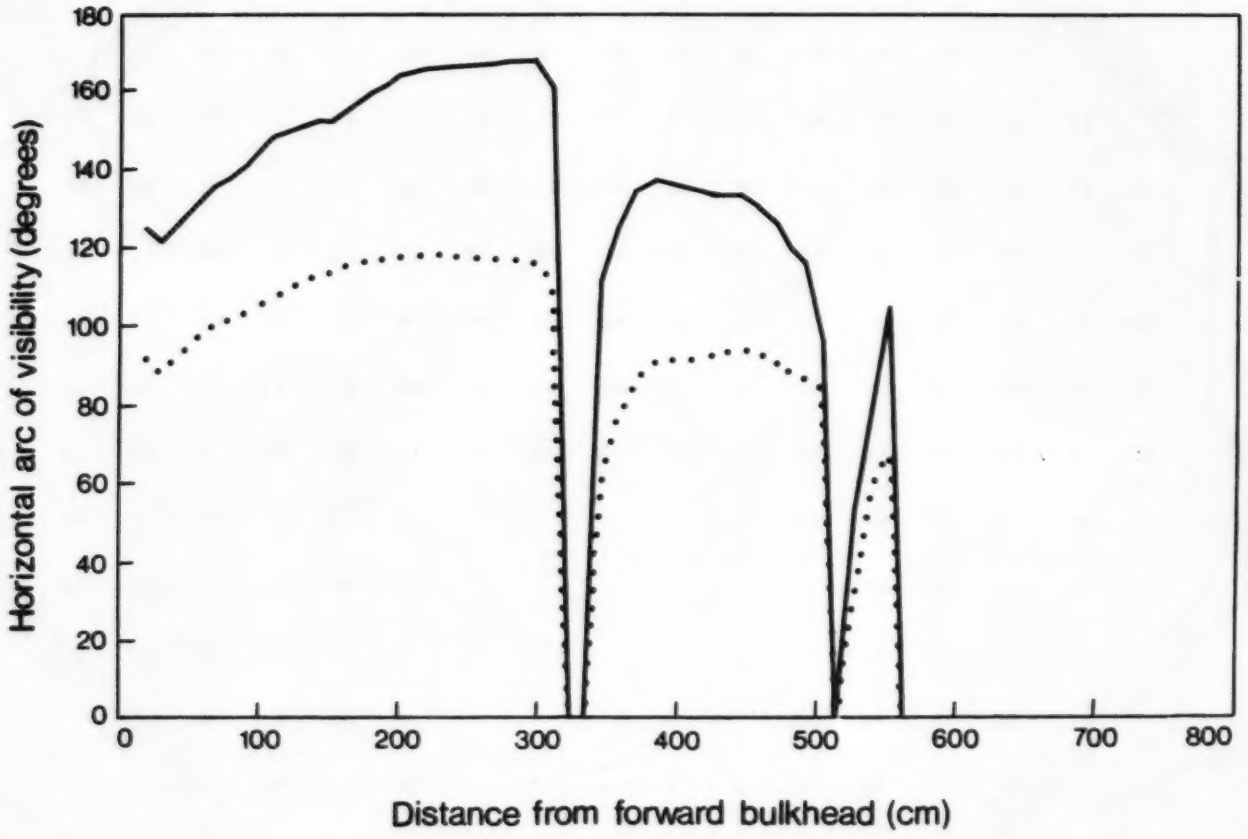


FIGURE 18

Comparison of arcs of visibility along the centerline for 29 windows versus 15 windows



4.7. Side Pelori Positions

Requirements:

a. These pelori should provide sight lines through sectors on their respective sides of the ship which cannot be obtained at the centreline. Important sectors for coverage include (27):

i. arcs directly on the beam (± 6 deg. unbroken arc)
ii. arcs directly forward (± 6 deg. unbroken arc)

b. The side pelori should provide a view of the sea from 15 deg. below the horizon (maximum declination of the compass card) to at least 8 deg. above the horizon.

c. The pelori should be mounted on a slide permitting sufficient travel to compensate for close wooding. Generally the travel of a pelorus should be greater than the inter-window distance.

d. The railed stand should be oriented so that it is parallel to the closest window. This has three benefits:

i. the gain from pelorus travel in terms of additional arc is maximized;
ii. the obstruction to movement between the window and pelorus is minimized;
iii. sighting from behind the pelorus is assisted by minimizing the amount of rail between the observer and the pelorus.

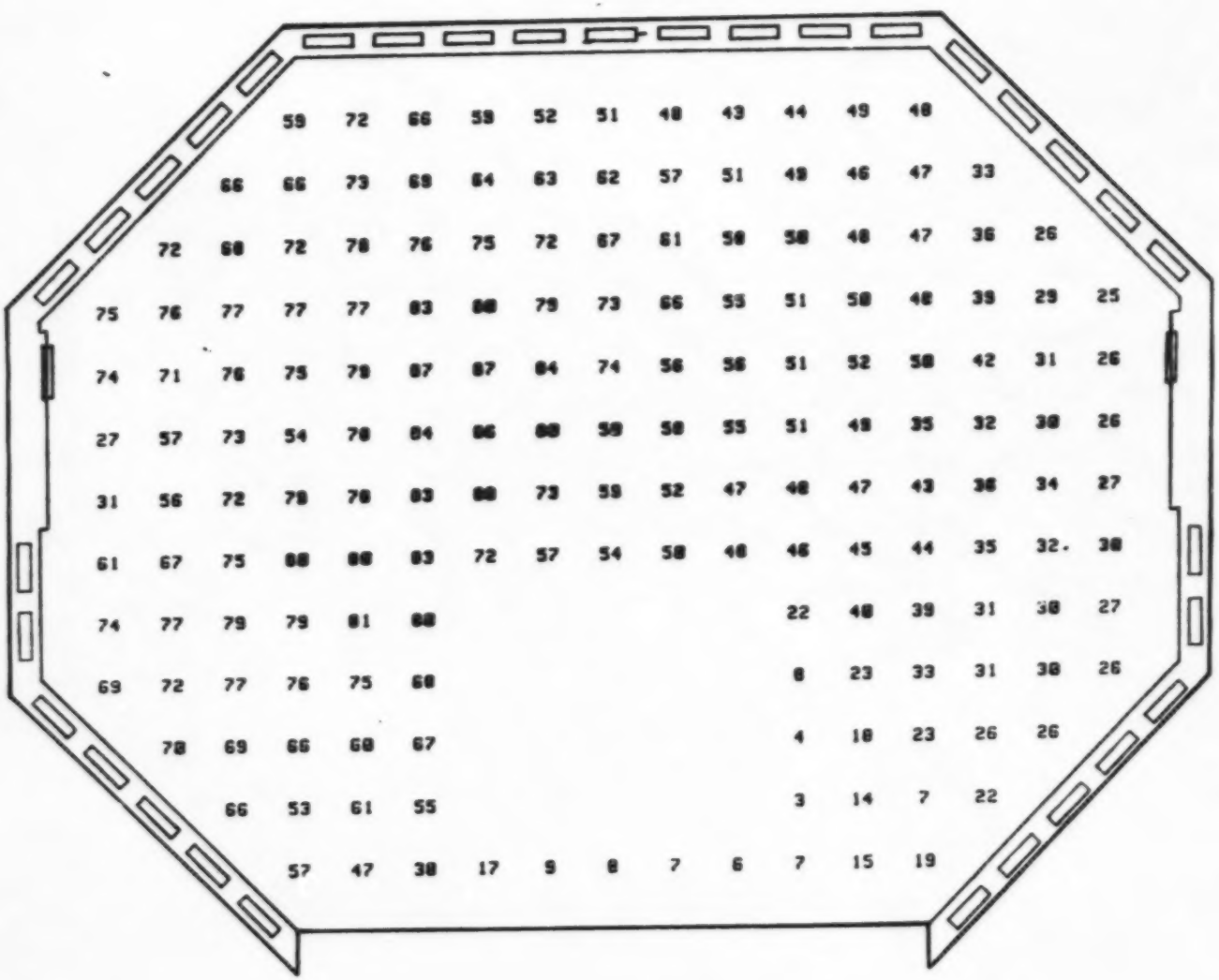
e. The side pelori should be positioned so that their operators have immediate access to other pelori. This is necessary because certain lines of sight may be obstructed throughout the full length of a pelorus's slide by personnel along the windows.

Observations:

The optimal position for the side pelori with respect to horizontal arcs of visibility is dependent upon the bridge window layout chosen. The two window layouts under consideration include the existing layout of 35 windows and the proposed layout.

FIGURE 19

Arcs of visibility to port in the existing DDH 280 bridge



For the 35 window layout, the totals for horizontal arcs of visibility to port are shown at selected positions in Fig. 19. The largest arc (80-87 deg.) occurs 1-2 metres to port of the central stanchion. However, the size of arc directly on the beam (8 deg.) is insufficient from this position.

A pelorus positioned 1.5 metres medially from the port window ahead of the door offers a larger 17 deg. arc directly on the beam. The total for the horizontal arcs of visibility to port at this position is 76 deg. However, 610 mm travel along a slide oriented for-aft would permit compensation for near wooding; effectively increasing the visibility to port to 150 deg.

For the 29 window layout proposed in Section 2.5, the totals for horizontal arcs of visibility to port are shown at selected positions in Fig. 20. The highest totals (84-90 deg.) occur in the same general area as the 35 window layout. Again, the small size of the arc (8 deg.) directly on the beam is insufficient.

A pelorus positioned 1.4 metres medially from the port window ahead of the door offers a larger 18 deg. arc directly on the beam. The total for the horizontal arcs of visibility to port at this position is 80 deg. However, 610 mm travel along a slide oriented for-aft would permit compensation for near wooding; effectively increasing the visibility to port to 160 deg.

Recommendations:

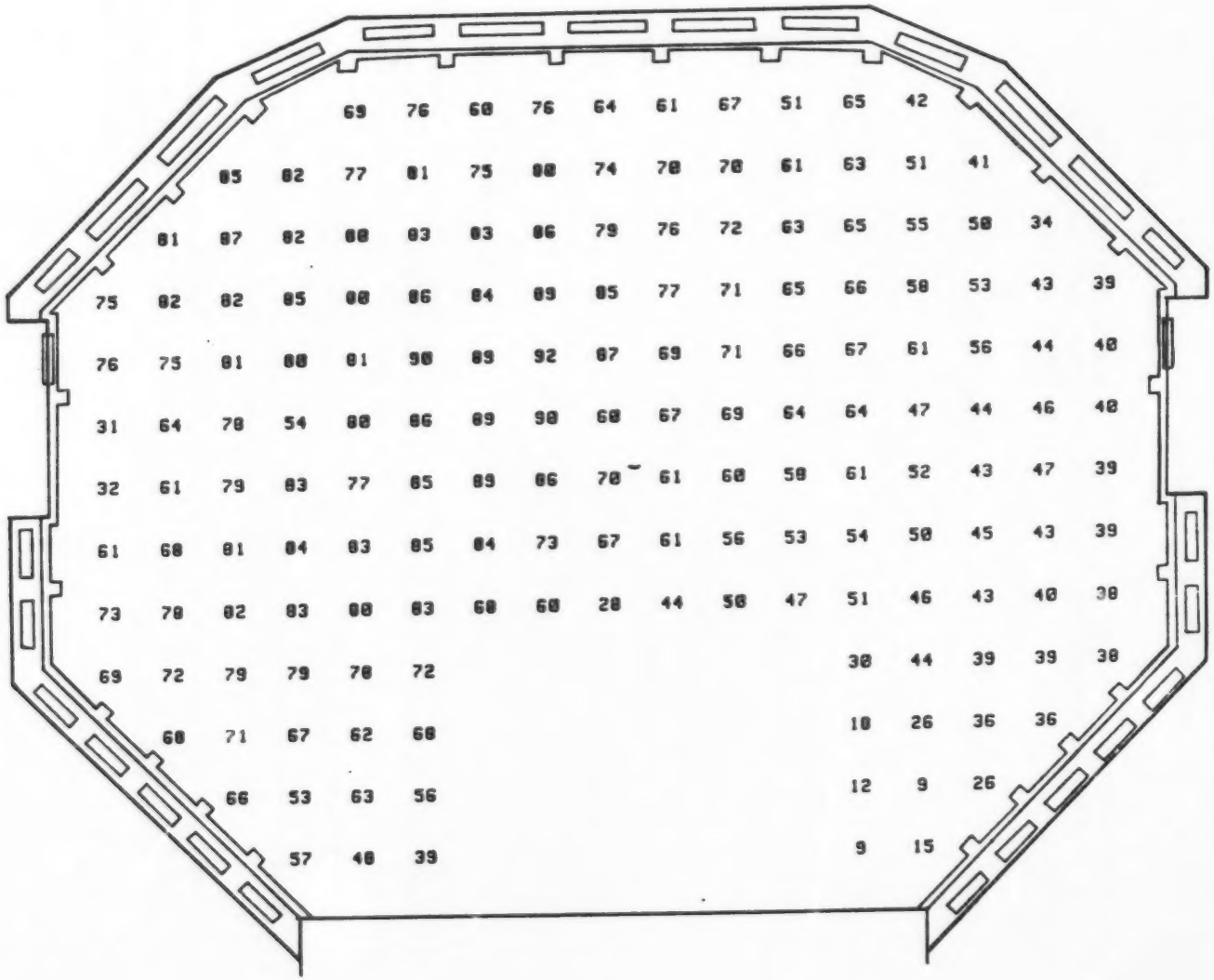
Each side pelorus should be set on a pedestal with a slide oriented in a fore-aft direction. This slide should permit travel of 610 mm.

For the existing window layout, the side pelori should be centred directly aft of windows 12 and 24 (see Fig. 12, Section 2.5), approximately 1.5 metres from the side bulkheads. The aftermost portion of the slide should be centred on windows 8 and 28 so that bearings can be taken directly on the beam.

For the proposed window layout, the side pelori should be centred directly aft of windows 11 and 19, approximately 1.4 metres from the side bulkheads. The most after portion of the slide should be centred on windows 8 and 22 so that bearings can be taken directly on the beam.

FIGURE 20

Arcs of visibility to port with the proposed window layout



CHAPTER 5

OVERALL RECOMMENDATIONS

Implicit in the conclusions derived from the analysis of the DDH280 bridge visibility has been the assumption that recommendations would be directed toward improvement of the existing bridge. These recommendations are specific to the DDH280 bridge and clearly insufficient for the design of a new bridge. However, the principles used to establish the recommendations are general, and in large part they are applicable to a wide number of bridges.

The specific nature of these recommendations is primarily due to the constraints imposed by the existing bridge:

- the outer dimensions and shape of the enclosed bridge;
- the area and dimensions of the bridge wings;
- the six stanchions in the central bridge.

It was also assumed certain major modifications of structure and equipment would be undertaken including:

- removal of the forward bridge platform;
- relocation of the chartroom aft;
- relocation of all bridge consoles and desks.

Due to uncertainties regarding modifications to increase the window size, recommendations concerning placement of key workstations and pelori have been made addressing both the existing window layout and the proposed layout incorporating the larger sized windows.

Horizontal visibility requirements have established a number of essential changes:

- closed circuit television cameras should be placed such that blindspots on the stern and along the sides of the ship are removed;

- the size of the windows in the forward bridge should be increased from the present 650 X 495 mm to 635 X 864 mm as proposed for the CPF bridge;

- the number of windows and mullions in the forward bridge should be reduced by incorporating the larger size windows and inserting corner windows at angles 22.5 deg. from the forward bulkhead. The priority for window replacement, in decreasing order of importance, should be:

  i. installation of the corner windows;

  ii. replacement of the three side windows with two larger windows;

  iii. replacement of the seven forward windows by five larger

windows.

- the chartroom should be moved aft against the aft bulkhead of the bridge so that all the windows can be used from the centre-line conning position;

- the insulation around the mullions should be reduced. Along the forward bulkhead this reduction should be sufficient to permit an inter-window spacing of 165 mm.

Vertical visibility requirements established further essential changes:

- the maximum height of the standing height consoles in the forward bridge should be 1210 mm plus an additional 140 mm for every metre aft of the forward windows. For example, those consoles placed 770 mm aft of the forward bulkhead, in order to permit passage along the windows, should have a maximum height no higher than 1320 mm.

- the after edge of the CO/OOW console should be no further than 2000 mm from the forward windows in order to accommodate a view of the ship's stem while standing behind the console;

- sit-stand seats should be provided for bridge personnel who need a clear view through the windows. Seat height for these individuals should be 490 mm plus an additional 140 mm for every meter the seat is aft of the forward bulkhead. This will permit a view from the stem of the ship to the horizon.

- the Helmsman's console should be no higher than 1210 mm. This would permit a seated man to see to the horizon provided his seat was adjustable between 380 mm and 500 mm.

- communications between the wings and the helm should be upgraded to provide a direct two-way voice link between the OOW on the wing and the Helmsman. Conning displays including rudder angle and engine repeats should be available on the wings.

The height of the windows should not be raised. The present window height permits a view from the stem of the ship to the horizon from the centreline conning position for individuals with a standing eye height at or above the 5%ile.

Workstation requirements established a need for several additional changes:

- the OOW, CO and Helmsman consoles should be placed 770 mm aft of the forward bulkhead to permit free passage along the windows and good visibility immediately behind each console,

- the OOW and CO consoles should be placed on the centreline or just off centre to starboard. The Helmsman's console should be placed on the centreline or just off centre to port,

- the engine throttles should be placed on the port side of the Helmsman's console,

- the distance between the centreline conning position and either the Helmsman or the OOW/CO console should be no greater than 2 metres,

- the chart table should be placed forward facing with good access to the wing to wing gangway. The maximum height of the backboard on the forward edge of the chart table should be 1390 mm,

- the centreline pelorus should be placed two metres aft of the forward window. The height of the pelorus sights should be 1490 mm above the deck,

- each side pelorus should be set on a pedestal with a slide oriented in a fore-aft direction. This slide should permit travel of 610 mm. The height of the pelori should be no lower than 1380 mm above deck,

- for the existing window layout, the side pelori should be centred directly aft of windows 12 and 24, approximately 1.5 metres from the side bulkheads. The aftermost portion of the slide should be centred on windows 8 and 28 so that bearings can be taken directly on the beam,

- for the proposed layout with larger windows, the side pelori should be centred directly aft of windows 11 and 19, approximately 1.4 metres from the side bulkheads. The aftermost portion of the slide should be centred on windows 8 and 22 so that bearings can be taken directly on the beam.

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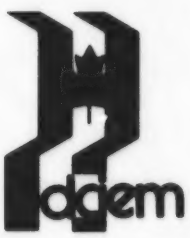

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